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Standards and Standard Materials of Ceramics

Current Policy of Standardization and Standardization of Ceramics

94FE0476A Tokyo CERAMICS JAPAN in Japanese Jan 94 pp 16-19

[Article by Kunio Sone, Standards Department, Agency of Industrial Science and Technology]

[Text]

1. Overview

1.1 Development of Industrial Standardization

Japan's industrial standardization began with enactment of standards for military procurement or standards for the purchase or testing for purchasing for government.

Standardization began as a formal system in April 1921 with the establishment of the Industrial Products Standards Uniformity Institute.

After World War II, there were big changes in industrial standardization. In 19·6 an Industrial Products Standards Institute was newly proclaimed to plan for redevelopment of standards to replace earlier standards which focused on products for military procurement. In June 1949, an Industrial Standardization Law was enacted to establish uniformly the concept of industrial standardization and to maintain and develop nationally uniform standards.

1.2 Aim of Industrial Standardization

Standardization carried out by the Japanese government has a big impact on the development of the country's industrial economy, improving the standard of living, and progress of national welfare. In recent years, expectations are rising that standardization will play a major role in the response to social problems such as an aging welfare society, emphasis on consumers, environmental problems, and promotion of the development and diffusion of new technologies.

1.3 Direction of the Establishment and Revisions of JIS

Establishment and revision of JIS will aggressively be pursued in ways "that help respond to new social problems." Moreover, aggressive moves will be made toward abolishing standards which do not fulfill the current role of JIS. This includes abolishing provisions for achieving policy goals which have already been achieved, such as export promotion and strengthening international competitiveness, and provisions which pertain to transactions and production within or between specified industries.

1.4 Need for International Standards

More than 40 years have passed since the enactment of the Industrial Standardization Law. The goals of standardization have changed with thetimes, particularly in recent years since the enactment of the GATT Standard Code which strongly calls for the harmonization of international standards as a means of eliminating nontariff barriers. Accordingly, the "Proposal for Long-Term Planning for the Promotion of Industrial Standardization," put out by the Japan Industrial Standards Institute in June 1990, strongly called for "responding to new social problems" and "promotion of international standardization."

Japan has enjoyed the benefits of international standardization. But until now it would be difficult to say that Japan has made sufficient substantive contributions, except for economic contributions.

In many cases, European countries have made their national standards agree with ISO or IEC standards. This is true of JIS standards in very few instances.

Reforming this situation may be thought of as something that must be carried out once it is mentioned or as a simple international contribution or as something which, although voluntary, is a money pit without economic effectiveness. However, it would be good to aim for something that would be more fundamentally advantageous. People directly and indirectly involved with standardization understand that there are enormous risks in making mistakes about standardization and that companies can be seriously hurt. It is important that entire companies understand this.

1) Significance of International Standardization

International standardization is important because it makes possible the removal of technical barriers to trade, establishment of a scientific and technical foundation, and establishment of a base for fostering industrial development in developing countries. In view of Japan's economic and technical position, it is necessary that Japan establish a new idea appropriate to the significance of international standardization, rather than staying with the status quo, and that all of Japan aggressively participate in international standardization.

Until now Japan has passively deliberated on standards proposed by various foreign countries in deliberations on international standards. There have been few cases in which Japan has acted as the executive member country by presenting its own draft proposals or running a conference.

2) Aggressive Participation in International Standardization Activity

In the past there has been little Japanese interest in international standardization. There has been a sense that JIS and international standards cannot be harmonized because international standards weren't used domestically since no matter what decisions were reached on international standards, JIS applied within Japan.

However, as economic globalization proceeds, it has become dangerous domestically and impermissible internationally for Japan to continue distinguishing between "domestic" and "international."

Of course, since international standards are established only when there is consensus, there are times when international standards cannot fully meet Japan's domestic needs. It is not permissible for Japan to avoid incorporating into JIS the international standards on which there is international consensus. Accordingly, Japan must actively seek international understanding of international standards which take Japanese conditions into consideration. Furthermore, as JIS is established and revised, Japan must get involved in international standardization activity. Japan must try to establish and revise international consensus. In effect, Japan must try to make JIS and JIS proposals into proposals for international standards. Establishment of these principles will inevitably be linked to Japan's aggressive participation in proposing international standards, presenting opinions, and acting as an executive member country. This is how Japan will increase its contribution to harmonization of JIS and international standards and also to the creation of international standards which are an international asset.

It is undeniable that Japan has geographic and linguistic handicaps in participating in international standardization activities which have been centered in Europe. However, it is necessary to gain understanding and cooperation from the Japanese players who are key to international standardization and to deal with organizational and continuation issues, so that these conditions can be overcome and Japan can participate aggressively.

2. Itemized Discussion

2.1 Position of Ceramics in JIS

In order to promote the establishment and revision of JIS for ceramics, it is necessary to position ceramics in terms of the above-mentioned response to new social problems and in terms of international standardization activity.

For the purpose of positioning, it is easiest to divide ceramics into new materials and existing materials.

2.2 Standardization of New Materials Ceramics

New materials ceramics are fine ceramics or new glass. The basis for this is the use of fine ceramics and new glass in "Proposal for Promoting Standardization of Ceramics" issued by the Japan Industrial Standards Institute in 1987.

The rapid technological changes of recent years have resulted in the development of many new materials and some are already in use. Not only efforts to produce superior materials are needed to promote the use of new materials ceramics. It is also important to establish materials evaluation technology that can accurately evaluate the materials' characteristics.

Manufacturers and users are unable to obtain technical information and reliable data without the establishment of methods for testing and evaluation, so they cannot proceed smoothly with development. For example, it is not possible to compare bending strength performance of materials if their measurement methods diverge. As a result, users must conduct their own tests of materials they wish to compare.

Standardization related to new materials is significant in various ways. Standardization is necessary on the following points.

1. Avoiding Confusion by Standardizing Terms and Symbols

Currently an assortment of technical terms and symbols are used in the development and application of new materials. In many cases this is very inconvenient. Accordingly, there is a need to first standardize terms and symbols so this confusion can be avoided.

2. Providing Data That Enables Comparison by Users and Manufacturers

Currently it is important to assure reliability for promotion of the development and application of new materials to proceed smoothly. Fair evaluation of new materials' characteristics is important for this to be achieved. However, the reliability of testing and evaluation is not fully established since there are many disagreements even about the premises upon which testing methods and evaluation criteria are based. As mentioned above, this causes inefficiencies for users and manufacturers. Standardization of testing and evaluation methods which creates data which is comparable between users and manufacturers is essential for promoting efficient development and application of new materials.

Fine ceramics and new glass are positioned as contributing to "development and diffusion of new technologies as part of a response to new social problems." Surveys and research for standardization of new materials ceramics has been entrusted to the Japanese government. Many JIS standards are being created as a result.

Fine ceramics were newly established as TC206 by the ISO in April 1992 for which Japan was executive member country. From now on JIS will be established and revised as part of ISO proposals.

2.3 Standardization of Existing Materials

There are various types of materials, goods, and products made from existing types of ceramics such as glass and brick. It is difficult to generalize about their position in JIS. Moreover positioning varies for classification of standards' properties, i.e., product standards (those which regulate product shape, dimensions, quality, functions etc.), method standards (those which regulate testing, analysis, inspection, and measurement methods and operating standards etc.), and basic standards (those which regulate terms, symbols, units, series, etc.).

JIS standards must be set by Japan for products such as: safety glass which greatly impacts the people's safety; fire insulating brick and ceramic fibers which conserve energy and reduce environmental pollution by contributing to energy conservation and reducing users' energy consumption; public assets such as cement which contribute to the

people's welfare; and glass and other products for tests and analysis which assure the reliability of test and analysis results.

As mentioned in the overview, henceforth standards will not be set for products which: have already achieved their policy goal of promoting exports and increasing international competitiveness, relate to transactions and production within or between specified industries, or have been replaced by substitute products. By ceasing to set new standards and by aggressively abolishing existing standards, the designated goods will probably be removed from the JIS mark system.

Standards for methods—not only for ceramics—rank higher in importance than product standards among standards set by Japan. This is for the same reasons as mentioned earlier for the necessity of test and analysis methods for new materials.

Basic standards occupy the same position as method standards.

However, methods standards and basic standards are not needed by JIS if the standards are only used within one company or do not apply to the designated products. Then organization standards or internal company standards will suffice.

2.4 Position as Part of International Standardization Activity

Even though there is no clearly defined position for new materials, especially for fine ceramics, ISO (or IEC) standards exist or might be established. It seems that standardization is internationally seen as necessary in fields such as ISO's TC33 (fire-resistant materials), TC48 (glass vessels and implements for physics and chemistry experiments), TC74 (cement and lime), TC160 (glass for use in buildings), TC22/SC11 (grading materials), TC29/SC5 (grinding whetstone and grinding materials), and TC61/SC13 (composite materials and fiber reinforcing).

JIS standards are necessary to respond to these, to respond aggressively to international standardization activity, and particularly for the application of international standards.

3. Conclusion

The JIS standards which are necessary for Japan's response to new social problems and for international standardization activity will be established and revised as needed. Since JIS standards for ceramics should be established with this is mind, it is desirable that the organizations involved consider this as they cooperate in establishing and revising JIS standards.

International Trends in Standardization for Advanced Ceramics

94FE0476B Tokyo CERAMICS JAPAN in Japanese Jan 94 pp 2-23

[Article by Masataro Okumiya, Central Research Laboratory, Asahi Glass Co., Ltd.]

[Text]

1.Recent Trends in International Standardization

An international symposium was held in Nagoya, Japan, in April 1992. The symposium was a discussion about the need and feasibility of international standardization of fine ceramics. It was held in response to the request of Dr. Ikur [phonetic], the secretary-general of the ISO, the international organization for standardization. There were 50 participants from overseas and 250 from Japan. The content of the symposium was very substantive. The final panel discussion on the second day was an exchange of opinions about how to proceed in the field of fine ceramics with the issue of early standardization (advance standardization) of new materials. Finally, a statement known as the Nagoya Declaration was issued calling for the ISO to establish a technical committee (TC) for fine ceramics. Around the time of the symposium Japan formally applied to the ISO for the establishment of a fine ceramics technical committee. ISO headquarters in Geneva sent out documents asking member countries about their interest in participating. Balloting conducted over the summer vacation yielded a majority in favor of establishing the committee and five member countries that were highly interested in participating (P-members). In November it was decided to establish formally a fine ceramics technical committee as TC206. The P-members at that time were Japan, the United States, Korea, Indonesia, and Belgium. Japan, which had suggested the committee, became the executive member country and the United States became the presiding country. Preparations proceeded smoothly toward the first meeting of the committee one year later. However, a worrisome situation developed when P-member Belgium resigned in early 1993. ISO regulations require five countries for establishing a committee and there was uncertainty for awhile over how to treat a committee that shrank to four members. Readers will notice that no European countries were participating. This was a sign of their opposition to the committee because they had little leeway for assigning personnel to the committee since at that time the European Standards Coordinating Committee (CEN) has just begun its activities. Immediately after Japan was formally appointed executive member, it named Takashi Sugano as secretary. The United States named Dr. Schneider of the National Institute for Standards and Technology as chairman. Then the informal participation of European countries was sought. In 1993 the committee sent an observer to the CEN committee to explain the situation.

On 21 July 1993, to fulfill its role as country-in-charge and to support secretary Sugano, Japan began the All-Japan International Standardization Promotion Research Institute with Toshito Ohara, president of Nihon Gaishi, as chairman. The Institute's membership consists mainly of interested corporations such as members of the JFCA (Japan Fine Ceramics Association) which has been applying itself to setting JIS standards for fine ceramics. The main organizational members are JFCA, JFCC (Fine Ceramics Center), and Japan Ceramics Association. Two

committees have been set up in the institute. One is the executive member country business committee chaired by Tohoku University professor Masahiko Shimada. The committee holds discussions so that proposals can be made from a neutral and fair viewpoint for the actual promotion of international standardization. The other committee is the domestic business committee chaired by Yokohama National University professor Katsutoshi Yoneya. The committee discusses the pros and cons of points brought up by the ISO/TC and decides on Japan's opinions. In September both committees began preparing for their first meetings.

The news came from ISO headquarters that the number of P-members grew to eight. This relieved the uneasiness from the beginning of the year so international standardization activity could begin in earnest. The newly participating P-members were: Australia, Russia, Jamaica, and Malaysia.

Now that it is certain that the TC will actually become active, there's a greater possibility of European participation. Invitations for European participation have been renewed. It is desirable that participation from around the world be achieved by the time of the first conference in January 1994.

In the midst of a world-wide recession, it is not easy for countries to pay travel expenses for participation in every conference. The responsibility of country-in-charge Japan is to run a conference which minimizes that burden and to minimize the costs of drafting ISO standards. For a start, Japan proposed using the November 1993 Pacific Rim Meeting in Hawaii attended by many participants as a place to make preparations for the TC committee's first meeting.

2. What is International Standardization of Fine Ceramics?

What is standardization? It is common sense to reply that it is the creation of standards or the deciding of standards. The activity about to begin has the creation of standards as its goal. However, there are many worrisome questions about the standardization of fine ceramics which have yet to fully mature because of their short history and which are not yet widely used. Is it too early to standardize ceramics? Will standards quickly be outdated by technological advances? Will the creation of half-baked standards impede future technological progress?

It is generally understood that until now standards have been created for technologies that have spread and become established. As a result,once standards were established, they were expected to be authoritative and reliable since one had peace of mind about going ahead with production and transactions.

Recently in technical fields there are high hopes for new materials. There is the impact of materials that achieve what was only dreamed of before. However, it is undeniable that new materials are under development. According to the old concept of standardization, it would be safe to leave new materials outside the framework of standardization. However, new materials aren't being created simply to create new fads. They are created with the unmistakable goal of application as industrial materials. When new materials appear the least bit interesting, the number of people trying to develop them swells dramatically and they also become involved in transactions. New materials should not be excluded from standardization simply because they do not fit into the old concept of standardization.

For about a decade the ISO has been considering how to handle standardization of technological advances in rapidly advancing fields such as new materials. Japan's Isao Yamashita, chairman of the ISO from 1986 to 1988, created a chairman's advisory committee on technology trends (known as ABTT) within ISO. The committee asked the world about the need for standardization of early stage technologies. In 1987 JISC (Japan Industrial Standards Committee), Japan's window on the ISO, organized a special committee which carried out surveys and research on the state of advance standardization in three new materials fields of ceramics—metals, polymers, and new glass. JFCA's standardization activities began one-half year before the special committee, but from the beginning it dealt head-on with the issue of advance standardization raised as an issue at the ISO.

The difficulty of advance standardization lies in achieving both rapid establishment of standards and their stability. This requires that those involved be foresighted about technology trends.

3. Advance Standardization Promotes Technological Progress

Until now industrial standardization has aimed for fairness in transactions rather than for progress in science and technology. Advance standardization is distinguished by its emphasis on scientific and technological progress. The trends of advance standardization would probably be as follows. Standardization contributes to the development of the field of new materials by encouraging R&D and application of materials. When the industry grows, the standards will be used to evaluate product quality. As the industry grows, the role of standards in contributing to fair transactions, as they did under the old system of standardization, will grow. In the latter part of their life, the standards will be very close to the old form of standards. To those accustomed to the existing system, it will seem as if things have been turned upside down. However, it seems as if advance standardization fits more naturally with the timetable of the development of new materials.

For advance standardization to work, test and evaluation methods must be standardized. Objective measurements are necessary since new materials have distinctive characteristics and capabilities. New materials have new characteristics that cannot be captured by existing test and analysis methods. Accordingly, the development of new

materials must include the development of test and analysis methods that can measure their characteristics. New materials thought up by R&D are generally developed in conjunction with comparison of capabilities and characteristics by their developers. This comparison is the starting point for new materials standardization.

If your own data cannot be compared with measurements in an article, the value of the article is halved. It is impossible to decide which material to buy from a catalog if the numbers in a catalog cannot be compared. It seems obvious that comparisons should be possible from the beginning, but it is not easy to achieve that. Standardization of new materials is meant to overcome this difficulty.

Let's look at the example of bending strength. JIS' four-point and three-point methods of measuring bending cannot usually be compared. The JIS four-point method can't be compared with the ASTM or DIN four-point methods. International standardization is necessary. However, it isn't just a simple matter of internationally standardizing the world's best or most widely used method. Of course there's a need to look for the most technically rational method, but there may not be just one. It would be nice if several could be standardized and still allow for comparison.... That should not rejected as impossible without consideration. There is a need to try developing an "open material" type of material sample and collecting comparative data that would make it possible to change between different measurement methods. Open materials are samples with common characteristics produced by what are currently considered to be usual (standard) industrial methods. Production methods are kept as open as possible and the samples' characteristic values are kept within a range regardless of how they are produced. The Nagoya Declaration included an item about open materials. For a more detailed explanation of open materials, see "*FC Report,*" Vol. 11, No. 3, 1933.

The international standardization of fine ceramics includes the development of open materials. It includes a very R&D-oriented aspect as well as a very practical aspect oriented toward industrial development. Japan, which is one step ahead in the commercial development of fine ceramics, has a duty to contribute to the world by being open rather than keeping its experience to itself. The proposal and application of new concepts is necessary for responding to the technological progress which constantly affects standardization. The people who bear this responsibility should be flexible and not bound by existing concepts. The standardization movement is very dynamic and must continue into the future, so it's important that young people understand standardization.

Chemical Analysis and Reference Materials of Ceramics Raw Materials

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[Article by Kakuzo Tada]

[Text]

1. Introduction

The methods of analysis for which the raw materials subcommittee's subpanel of the Japan Ceramics Association has drafted or helped to draft Japan Industrial Standards (JIS) or Japan Ceramics Association regulations (JCRS) and the reference materials (JCRM) which are distributed by the Japan Ceramics Association are as follows.

Methods of analysis: JIS (Japan Industrial Standard) M8852 - 1972, 1976 (silicate analysis method); JIS M8853 - 1973, 1976 (feldspar analysis method); JIS M8854 -1974 (fire-resistant clay analysis method); JIS M8855 - 1977, 1991 (agalimatolite analysis method); JIS R1603 -1987 (silicon nitride powder analysis method); JCRS (association standard) 101 - 1978 (measurement method for ash-phosphorus pentaoxide in siliceous materials or alumina silicate ceramics; JCRS 102-1979 (silicon sand analysis method); JCRS 103 - 1984 (analysis method for ceramic materials high in alumina); JCRS 104 - 1993 (chemical analysismethod for impalpable powder used in fine ceramics).

Standard samples: JCRM R301*, 302 (baked bauxite), JCRM R401*, 402*, 403*, 404**, 405**, 406**, JCRM R501, 502 (zircon sand), JCRM R601*, 602, 603** (fire-resistant clay), JCRM R651 (alum shale), JCRM R701 (feldspar), JCRM R801*, 802 (pagodite), JCRM R001*, 002*, 003, 004, 005 ([silicon nitride powder]), JCRM R011 ([sintered silicon nitride]), JCRM R021, 022, 023 (silundum powder), JCRM R031, 032, 033 (alumina impalpable powder used in fine ceramics).

* = out-of stock;

** = in preparation.

Next will be the story behind how these were created.

2. How Things Happened

In an introductory article called "Draft Proposal for JIS Silica Analysis"[1] it is written that a committee was set up in June 1970 by the raw materials subcommittee's chemical analysis subpanel to draft JIS standards. However, preparations had begun before the first meeting in January 1970 of the raw materials subcommittee's chemical analysis subpanel.

In August 1969 the Agency of Industrial Science and Technology asked Tadashi Fujinuki (in the geological survey bureau of that time) for cooperation in creating JIS standards for analysis methods for materials such as silica, feldspar, fire-resistant clay, and talc. A July 1969 report on a 1968 "Survey Related to Minerals and Metal" entrusted to the Japan Science and Technology League Foundation included this statement: "There are eight analysis methods (rock phosphate, silica, feldspar, talc, barite, alumstone, asphalt, and fire-resistant clay) which are not among the 41 analysis methods for minerals designated by law as JIS

standards according to the third article of the Mining Law. It is desirable that these become JIS standards." This appears connected to Fujinuki since he was a member of the survey bureau.

Fujinuki planned in the board of governors through Takeo Okano of the raw materials sub-committee (then the geological survey bureau), winning agreement to establish a chemical analysis sub-panel. Subcommittee head Masao Naito (then of Asahi Glass) assigned Tadashi Fujinuki, Hajime Ishii (then of the Inorganic Substances Laboratory), Kakuzo Tada (then of Toshiba Shibaura Electric), and Michio Fuse (then of Asahi Glass) as preparatory committee members. They conducted several meetings and, in conjunction with the glass committee's subpanel number two (chemical analysis), they discussed how to proceed with drafting the first proposal for reference materials and JIS analysis methods. As a result, they decided to take up silica for use in glass, on which the glass subcommittee has finished doing cooperative experiments. They also reported the start on this made by chairman Kakuzo Tada and secretary Tadashi Fujinuki and they won approval from the executive committee in December 1969.

The subpanel was started to cooperate in the drafting of JIS standards, but it primarily considered itself as a place where members could exchange knowledge and technology for developing analysis methods for all ceramic raw materials. Later, in the subpanel rules created in April 1981 when Noboru Yamamoto (then of Japan Glass) was head of the subcommittee, it was written: "The analysis subpanel does research on analysis methods for ceramics raw materials and aims to contribute to the advancement of analysis technology for ceramics."

3. Means of Analysis

The method of analysis introduced by the abovementioned "Draft Proposal for Silica Analysis Method" was based on the "JIS Means for Chemical Analysis of Ores and Metal Materials" from the materials standards section of the Agency of Industrial Science and Technology. The details of this draft were altered according to the deliberations of specialist committee members. The analysis methods established later for feldspar, fire-resistant clay, and pagodite were all based on this document. This is why the methods of analysis of JIS' G, H, and M departments are uniform. JIS Z8301 (standards signposts is probably the only exception. Lack of uniformity stands out in the R department's analysis methods for glass, cement, grinding materials, carbon products, and gypsum. All Japan Ceramics Association standards are written in conformity with JIS chemical analysis methods.

According to the original schedule, talc was supposed to be taken up after fire-resistant clay, but in fact pagodite was next in 1976. This was newly taken up because JIS M8106 (testing methods for pagodite clay used in paper-making) contained no analysis methods.

4. Distribution of Reference Materials

Two types of silica for use in glass were the first cooperative experimental reference materials. With the expectation that they would become reference materials of the future, 20 kg units of each type of silica were received from Tokai Industries and they were pulverized so they could pass through a 200 mesh sieve for measurement by fluorescent X-ray analysis. Since pulverization used a corundum ball, the undissolved remainder was mixed in using hydrofluoric acid. Ten out of every 200 vials were selected at random and measured for iron by fluorescent X-rays to assure homogeneity.

Later the subpanel added low-grade reference materials, creating a set of three (JCRM R401, 402, 403). At that time the sale of reference materials was not within the scope of the Ceramics Association's business bureau. In February 1973 their sale was entrusted to the Science and Technology Co. which sold soda coal glass reference materials[2] created by the glass subcommittee of the Japan Stand Reference Material Committee.

The Association began distributing reference materials after Tatsuo Oba became chief of the business bureau. Upon this occasion, in March 1981, regulations were codified for the establishment and distribution of reference materials and it was specified that the establishment of reference materials required approval by the Association's preparation committee. At the same time, materials numbers' organization and certification values were reconsidered. Also a working committee made up of past and present chairmen and secretaries was set up and its regulations and the essentials of creating reference material analysis result charts was established in July 1983. For information on how certification values (standard values) were determined, see Fujinuki's introductory article.[3]

5. Ceramics Association Standards

When JIS work ended, the work of the Ceramics Association started. Its first result was JCRS101 (measurement method for phosphorus pentaohide in silicic acid or alumina silicate ceramics raw materials). Next came JCRS102 (silicon sand analysis method) and JCRS 103 (analysis method for ceramics raw materials high in alumina). Reference materials were made for silicon sand, baked bauxite, and alum shale. With sets of two, the first was used for consideration of method and the second for experiments for calculating permissible differences.

6. Appearance of Man-Made Raw Materials

Analysis methods for silicon nitride and silundum became an issue once the fine ceramics of which they are a component began to attract attention. The subpanel decided to develop analysis methods for man-made raw materials in tandem with natural raw materials, set up a man-made raw materials research group (known then as WG) under the subpanel, and began cooperative experiments on silicon nitride in 1980. Cooperative experiments were carried out using for reference documents received

from Asahi Glass on international cooperative experiments carried out by NASA in 1979. NASA's items for analysis included carbon and oxygen, but since the necessary special measurement apparatus existed only at three ceramics analysis facilities, the cooperative experiments had to share it. When it [JCA subpanel] was entrusted with drafting a proposed standard for chemical analysis of silicon nitride powder in 1982, conditions had not changed much. The chemical analysis subpanel created a proposal drafting committee and presented its report in March 1985.

However, the method for measuring aluminum, iron, and calcium using pressurized decomposition and atomic absorption spectrochemical method had a notice of infringement upon a Toshiba patent under application. This method had been used in the above-mentioned NASA cooperative research. AMMRC PTR73-5 (AD-761104) 1979 used luminous spectroscopy, but with the same dissolution solution. To cut a long story short, the proposal drafting committee believed that the patent would not be granted. In February 1985 a formal objection to the patent was lodged according to directions from the Agency of Industrial Science and Technology. Toshiba responded in October 1985 and counterarguments were carried out according to written reports of objections in February 1986. Toshiba presented judgement request documents in July 1986 and the judgement request was withdrawn in November 1986. Because of this, it took four and a half years from the draft proposal for JIS R1603 to be established.

JCRM R001, 002—reference standard materials for silicon nitride powder together with sintered standard materials, went on sale before a JIS standard could be set for its analysis method (1985). These reference materials held 20 grams. They sold out almost immediately because these reference materials were not available overseas and because they were welcomed as weighing standards because machine methods of weighing nitrogen had just come into use. Because of this they were replaced by a set of three that went on sale as JCRM R003, 004, and 005 in 1988. This replacement was due to the activities of the above-mentioned reference materials working group.

7. Conclusion

In 1990 a proposal was drafted for revising JIS R1603 and JIS R2901 (chemical analysis methods for chrome ores used for fire-resistance) and for the new establishment of "chemical analysis methods for silundum powder used in fine ceramics." These have not yet become JIS standards.

Reference materials like those of JCRM have recently been known as certified standard materials. So-called wet analysis methods are necessary for deciding certification values, but the number of seasoned practitioners of those methods is declining. A need is seen for increasing their number because of increasing demand for reference materials, but no solution is in sight. Japan's standard materials system is becoming a problem. It is impossible to foresee what form a new system will take, but the Japan Ceramics Association must be involved with it.

References

1. Kakuzo Tada, *Ceramics*, Vol. 6, 1971, pp 384-92.

2. Ibid., Vol. 4, 1969, pp 332-34.

3. Tadashi Fujinuki, "Bunseki [Analysis]," 1986, pp 724-25.

Standardization and Reference Powders for Particle Size Analysis

94FE0476D Tokyo CERAMICS JAPAN in Japanese Jan 94 pp 28-30

[Article by Junichiro Tsubaki, Japan Fine Ceramics Center]

[Text]

1. Introduction

Several principles of measurement are applied in measuring particle size and distribution of ceramics raw materials. Due to limited space, this article will focus on laser diffraction/scattering which is the most widely used method. The paper will cover the current status of particle measurement technology and the status of standardization.

2. Unrestricted Measurement Results

Since particle measurement is a kind of measurement technology, it seems natural that the same measurement results will occur if the same sample is measured according to the same principles of measurement. However, it is not unusual for measurement results to vary by several hundred percentage points and for reasons that are almost always unclear. It would be possible to use unrestricted measurement results if the causes of this dispersion were thoroughly understood. It may seem doubtful that this can be done, but it is not too difficult to handle differences of up to ten times for samples with broad distributions. Figure 1 shows an example. Figure 1 shows the results of several measurers using several different pieces of centrifugal precipitation light transmission-method measurement apparatus to measure alumina grinding material (composite sample). It shows that length is 50% of diameter and width is at the upper limits of measurement by the apparatus. As the figure shows, 50% of the diameter shows nearly 10% discrepancies. The fact that 50% of the diameter increases with the upper limits of measurement shows that the sample includes many particles that are larger than the upper limits of measurement. This dispersion occurs because that which should be measured is measured. This may seem like nonsense, but this appears to be a pitfall of an automated society which thinks that if you put a sample in and push the apparatus buttons then everything is okay. This is the greatest cause of dispersion. Figure 1 shows the

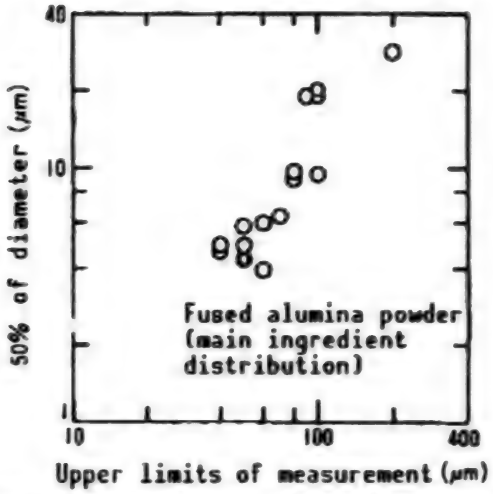

Figure 1. Influence of Particles Larger Than Measurement Range on Measurement Results

results from using the centrifugal subsided light transmission method, but the existence of particles larger than the upper limits of measurement is also the greatest cause of dispersion when the laser diffraction/scattering method is used.

3. Measurement Results Complete Until Here

According to people who measure, measurers are responsible for the dispersion of measurement results in cases where it is difficult to say they are innocent. Measurers also believe that measurement apparatus can be guilty.

In 1989 the Fine Ceramics Center (JFCC) called for participation in planning a multi-client study on "Systematic Comparison and Establishment of Measurement Technology for Apparatus Measuring Particle Distribution"[2,3]. The Center received self-sacrificing cooperation from Japanese equipment manufacturers and dealers. Six types of ceramics raw materials were used as samples in a round-robin test of equipment based on 22 different principles. Preparation of the samples and the measurement procedure was standardized as much as possible in order to reveal the abilities of the measurers and the pluses and minuses of the apparatus. The results of measurement using the laser diffraction/scattering method are shown in Figures 2 and 3 which show that measurement apparatus is also guilty. The degree of guilt is relatively light in cases such as that shown in Figure 2 where the distribution is relatively narrow for barium titanate with particle sizes in micron order. If the results of this kind of sample differ by twofold, then the skill of the measurer must be questioned. However, the apparatus is very guilty in the case of silundum samples with high refractive index of submicron particle refraction shown in Figure 3 where measurement results showed a threefold dispersion.

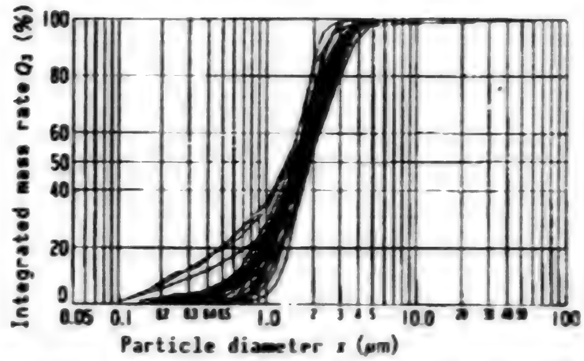

Figure 2. Measurements That Can Be Called Examples of Good Measurement Technology (Results of JFCC's first-stage multiple measurements of particle size; titanous barium oxide.)[2]

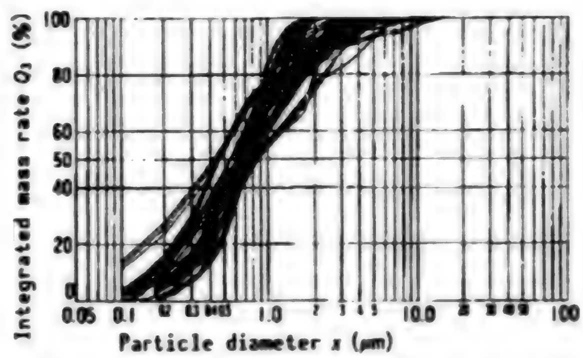

Figure 3. Measurements That Cannot Be Called Examples of Good Measurement Technology (Results of JFCC's first-stage multiple measurements of particle size; silundum).[2]

Troublesome Refractive Index

When particle size is the same or smaller than the wavelength of light, the particle refractive index has a big impact on the scattering behavior of light. As a result, almost all devices make it possible to enter refractive indexes. However, one must rely on physical properties handbooks for refractive indexes since it is impossible to measure them. There is no place to go for materials of which one does not know the name or which are composites. Even more troublesome is the fact that the documented value is not necessarily the optimal refraction index for that piece of apparatus. Figures 4 and 5 show measurement results for polystyrene latex (PSL) which is often used for evaluating particle size measurement apparatus because its particles are spherical and do not vary in size (single distribution). Figure 4 shows when documented values for refraction index are used. Figure 5 shows when optimal values were sought for each piece of apparatus by using estimates.[4] The figures show that documented values are not always the optimal values for each piece of apparatus. Accordingly, dispersion would

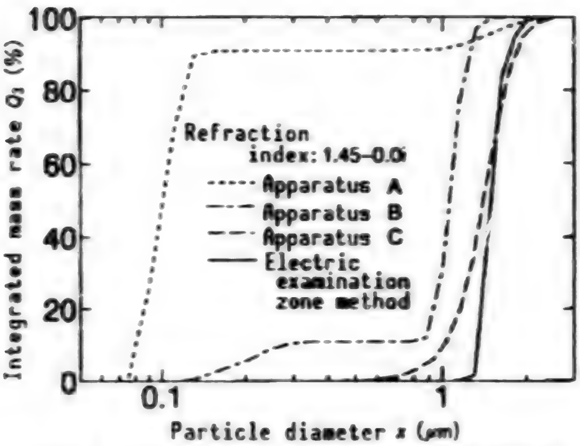

Figure 4. Example of Measuring PSL Single Distribution Particles Using Documented Value of Refraction Index[4]

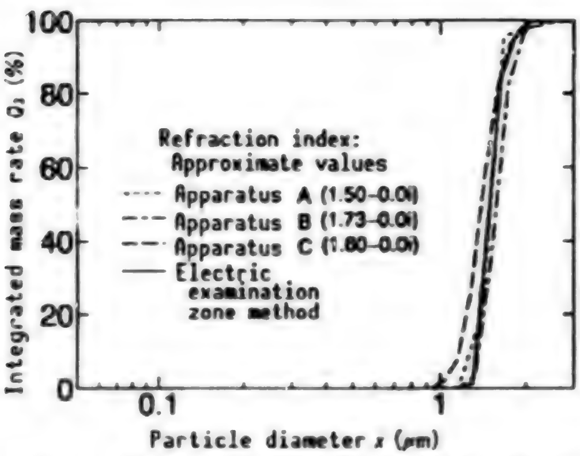

Figure 5. Example of Measuring PSL Single Distribution ParticlesUsing Estimated Values of Refraction Index[4]

shrink even further if optimal values were used in each piece of equipment used in measuring silundum in Figure 3.

5. Status of Standardization

Measurement results were not dispersed when everyone used the same apparatus with standardized sample preparation conditions and measurement procedures. It is possible to standardize sample preparation conditions and measurement procedures, but it is not possible to say that all of the ten or more kinds of laser diffraction/scattering method models are the same machine. However, it is possible to adjust the equipment according to the standard material so that their results are essentially the same, regardless of model.

For what kind of particles can particle size measurement apparatus be adjusted to treat as standard materials? First, particle shape must be spherical so that light scattered from the particles can be analyzed as light scattered from spherical particles. As close as possible to a single distribution of particle size is desirable for the particles treated as standard materials so that size can be directly measured by electron microscopes or SEM. Moreover, since measurement would not have much significance if there were only one particle diameter, the particles should be measured in submicrons or microns with as little gap as possible between the line-up of particle sizes. The particles' refractive indexes should differ since laser diffraction/scattering equipment is strongly affected by particle refractive index. Currently PSL, as mentioned above, meets three of these four conditions. However, since it is not possible to create submicron spherical single distribution particles with differing refractive indexes, it is not yet possible to adjust equipment using standard materials. However, conditions for standard materials are more flexible with particle diameters above 10 mm since they are not affected by refraction indexes.

The particle distribution preparation group of the Oil Substitute Standardization Survey and Research Committee is examining surveys and research with the goal of developing standard materials in this area. This research is also examining sample preparation and it appears there will be JIS standards in several years. Standards for the laser diffraction/scattering method are being created by ISO/TC24/SC4, but the standards are incomplete since they don't consider the influence of refraction indexes or equipment standardization.

6. Ability and Equipment Checks

It will take time to develop standard powders that can be used for equipment adjustment, but there is a very strong need for standard powders. As a second-best strategy, JFCC is distributing commercially sold powders to be used as standard powders under the name Refer Powders. The Refer Powders are characterized by the use of standard measurement procedures for sample preparation and measurement conditions that vary by principle and by each manufacturer and dealer measuring the powders according to standard measurement procedures. As a result they are distributed by equipment type and by sample type. If Refer Powders are measured according to standard measurement procedures and if measurement results agree with those of manufacturers and dealers, then measurers' abilities and apparatus condition is okay.

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3. Ibid.

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Standardization Report on High-Temperature and Structural Materials

94FE0476E Tokyo CERAMICS JAPAN in Japanese Jan 94 pp 40

[Article by Toshizumi Nishina, Shinagawa White Brick]

[Text] Since evaluation and testing methods were established for fire-resistant materials by JIS in 1950, additions and changes have been made according to the demands of the times. As of now, 64 standards have been established and are widely used. In 1993 work began on consolidation of these standards. The creation of JIS standards for evaluation and testing methods for fine ceramics has proceeded at a rapid pace since 1981. Currently 16 standards for physical testing methods are in preparation. Also, standard materials such as common sintered forms are being distributed by JFCC. These are ways in which standardization of high-temperature and structural materials is proceeding. Since this topic overlaps with other manuscripts, this article will focus on recent standardization activity related to creation of a JIS standard (JIS R2216) for fluorescent X-ray analysis of fire-resistant materials and preparation of a series of standard materials for the utilization of that standard.

Efforts are being made to establish together the standards document and the standard materials for working curve. This requires a great deal of time and effort, but it will enable reliable use of the standard, provide for raising standards of analysis technology for the entire industry, and by assuring that all use the same methods and standard materials it will make it possible assure fairness in transactions.

The series of certified standard materials prepared in this way includes five types of materials—clays, silicas, materials high in alumina content, magnesias, and chrome magnesias—and five series for a total of 52 samples distributed by the Okayama Ceramics Promotion Organization.

The characteristics of these systems of standard materials are discussed below. Figure 1 shows on one graph the Al_2O_3 working curve for three series: clays, silicas, and materials high in alumina. The graph shows that these three series cover almost entire composition range as a SiO_2-Al_2O_3 binary system. The certified fire-resistant materials series is prepared so that it can respond to most fire-resistant materials within a broad composition range.

Thus it is possible to conduct highly precise analysis of most materials of most compositions using measuring lines sought from certified values and X-ray strength. Figure 2 shows a case in which accuracy is markedly reduced by the influence of common components[kyoson seibun] in the case of the Fe_2O_3 measuring line for chrome magnesias. In this kind of case it is possible to greatly improve accuracy by using a coexisting element revision method of measurement according to JIS, as shown in Figure 2 (in the figure, the degree of accuracy improves from 1.70 wt% to

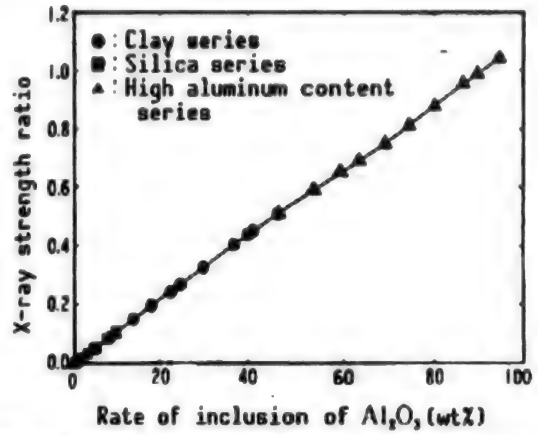

Figure 1. Measuring Line for SiO_2-Al_2O_3 Materials

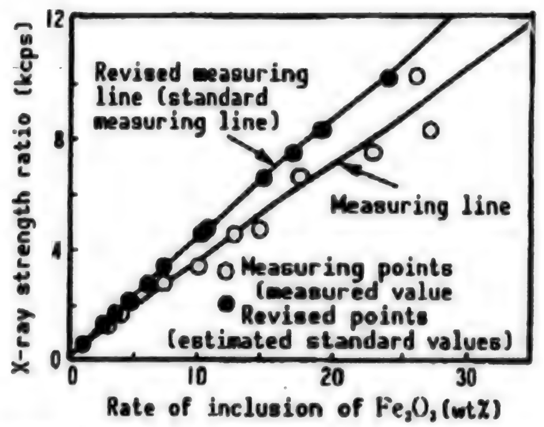

Figure 2. Relationship Between Measuring Line and Revised Working Curve for Fe_2O_3 Materials

0.09 wt%). The JIS standard andstandard materials established this time can be applied to measuring line methods and revised weight methods to enable more accurate analysis.

Standardization Report on Electronic Materials

94FE0476F Tokyo CERAMICS JAPAN in Japanese Jan 94 pp 43-44

[Article by Michihiro Murata]

[Text]

1. Introduction

Ceramic electronic parts are the main industrial product dealt with by the electronic parts subcommittee. There are few products which consist of electronic materials powders themselves. Accordingly, and due to space constraints, this article will give an overview of the current status of standardization which is limited to representative ceramic electronic parts.

2. Standardization Trends

JIS standardization of ceramic electronic parts has proceeded based on the current U.S. military standards (MIL) and the Electronic Industries Association (EIA) standards. However, recent standardization based on the GATT standard code has become the mainstream. JIS is proceeding with new establishment and revision of standards so as to harmonize with the International Standards Organization (ISO) standards and the International Electronic Standards Conference (IEC) standards.

As yet, few standards have been established because the creation of JIS standards requires long periods of deliberation and because there are many items for standardization. Because of this the Electronic Industries Association of Japan (EIAJ) and the Electronic Materials Association of Japan (EMAJ) have established committees of specialists to establish EIAJ and EMAJ standards. These standards become proposals for JIS standards or are widely used in the electronics industry as independent standards which are not JIS standards.

In addition, Japan is participating directly in IEC technical committees (TC) on standardization of technologies such as condensers, filters, ferrite, and surface mountings. EIAJ and EMAJ act as domestic Japanese deliberative bodies.

3. Ceramics Coding

The harmonization of JIS standards with IEC standards is proceeding and the standards correspond for the most part. Standards for layered ceramic chip condensers, in which the EIAJ took the lead, are being standardized by JIS and IEC (JIS-C6429, IEC-384-10, -10-1). EIAJ is proceeding with standardization for technologies—cylindrical chips, semiconductor magnetic condensers, and layered magnetic condensers—which are not included in the above-mentioned standards and being established respectively with the followingstandards: RC-2320 (1992), RC-2321 (1992), and RC-2322, 2323 (expected in 1993).

4. Piezoelectric Ceramics

Ceramic filters have been standardized by IEC, but not yet by JIS. EMAJ set up a technical committee and has been grappling with standards for piezoelectric vibrator since 1973. Electric testing methods for compiled piezoelectric ceramic vibrators were standardized in 1993 (EMAS-6100).

Standardization is under consideration for ceramic actuators. Proposals for standards for solid actuator terminology and testing methods are being drafted by the solid actuator subcommittee of the Japan Technology Transfer Association.

5. Ferrite Cores

JIS and IEC standards have been established for ferrite cores, but they are almost all concerned with standards for core and bobbin dimensions, methods of calculating the constants of dimensions, and terminology definitions.

The number of coil parts has expanded in response to trends for use of high frequencies, chips, and energy conservation. IEC has created five working groups under a technical committee (TC-51). The groups are investigating standardization of parts such as ferrite and pressed dust core parts with microwave magnetism, and inductance parts. With Japan as the executive member and EMAJ as the deliberative organization, work is proceeding on a new work item of standardization of ferrite materials with closed magnetic circuits, open magnetic circuits, and high magnetic fields.

6. Ceramic Sensors

NTC thermistors are standardized by JIS-C1611, C2570, C2571, and IEC-539 and 696 while PTC are standardized by EMAS-8201, 8202, and IEC-738-1, and -1-1. EMAJ is deliberating on revisions to IEC-539 and 738-1 which would make them reflect Japanese conditions.

EIAJ is dealing aggressively with standardization of other sensors. It is lining up standards for pyroelectric infrared ray, gas, humidity, and acceleration sensors.

7. Ceramic Matrix

Ceramic board standards include JIS-C2141, and IEC-672-1,2. EMAS has standardized methods for testing electric, heat, and mechanical characteristics, but it is in the process of revising them to agree with JIS standards. Standardization of alumina nitride and multilayered boards will be taken up in the future.

8. Varistors

There are no JIS standards for varistors, although EMAS-8301-8306 include general rules and testing methods for round-board ZnO and ring-type $SrTiO_3$ varistors. IEC-1051 standards for SiC and ZnO varistors do not reflect Japanese conditions. There are hopes for deliberations in surge suppressing device and parts technical committees (TC).

9. Final Note

Since it was not possible to include a list of standards in this paper, please consult the establishing organization if standards are needed.

Olympus Optical Co., Ltd., Develops Precision-Measurement Micromachine Based on AFM Principle

943FE0667A Tokyo NIKKEI SANGYO SHIMBUN in Japanese 26 Apr 94 p 5

[Text] Olympus Optical Co. has developed a precision-measurement instrument designed to measure surface forms of such microstructure as micromachines at a near-atomic-level precision. Applying the AFM measuring principle, on the basis of observations using interatomic repulsion, the micromachine is capable of measuring accurately the entire surface of the structure even if the surface has the unevenness in the order of micron (1/1000mm). With existing instruments, if a target structure is small, all one can do is to cut out a small sample and examine a portion of the surface. The Olympus Optical Co.'s future plan is to work on equipment with advanced capabilities using the newly-developed micromachine as a basic technology.

The maximum sample size which the prototype precision-measurement micromachine is capable of measuring is a 10cm-tall 18cm square. The area of 100 micron square of this sample can be measured in one setting, and, at that time, the micromachine can deal with a surface with the maximum unevenness of 10 microns. The surface can be measured at the precision level of 1/1000 microns in the horizontal direction and 1/100 microns in the vertical direction. As such, expectations for its use in precision-measurement of the micromachine parts and optical fiber edge surfaces runs high.

As is the case with the AFM, the surface unevenness is examined by bringing a probe near a sample and moving it up and down so that the repulsion force exerted by the sample surface's atoms can be kept constant while moving the probe forward horizontally.

What makes the newly-developed micromachine differ greatly from the AFM is its drive mechanism. With AFM, a precision mechanism probe is fixed and a head on which a sample is placed is moved three-dimensionally. With the precision-measurement micromachine, however, the probe is designed to move vertically by itself while the drive mechanism moves the head horizontally. This enabled the probe to move dynamically in a vertical direction. The point of the new precision-measurement micromachine is its design to maintain high precision even if the probe is allowed to move vertically by making the its mechanism compact.

With the AFM, if its base is to be moved vertically, because it is considerably heavier than the probe, it must be moved a great deal more slowly than the probe. For this reason, it was not possible to examine a structure with highly uneven surfaces within a practical time limit.

However, since the objects of the past observations, viz., semiconductor boards and optic disks, were relatively flat in terms of the order of microns, the existing drive mechanism was more than adequate for checking the surface of low-degree unevenness.

In the future, however, demand for detailed checking of the entire surface's unevenness in relatively small structures is most likely to increase. This means that the possibility of the precision-measurement micromachine being used as an observation equipment in the new micro field will be great.

Mitsubishi Electric Corporation Develops High-Power Gyrotron

943FE0667B Tokyo NIKKEI SANGYO SHIMBUN in Japanese 25 Mar 94 p 5

[Text] Mitsubishi Electric has succeeded in achieving the output of 1 MW (1 million watts) power using a gyrotron (a milliwave electronic tube) used in heating plasmas at the time of nuclear fusion reaction. The company was able to achieve the high power output by generating high-pressure, large-current electronic beams using an advanced electronic gun and by designing a resonant cavity to reduce power loss. The gyrotron is a nucleus device of a large-scale nuclear fusion system. Although three overseas research organizations already have succeeded in achieving a 1MW output, in Japan, this is the first time it was accomplished.

In the newly-developed gyrotron, an electronic gun which fires electronic beams, a resonant cavity which converts electronic beams into milliwaves, and a collector designed to collect electrons stripped of energy are arranged in a row and placed within the height of 2 meters. The company confirmed an output of 100 microseconds (1 micro = 1/1 million) at the high frequency of 120 giga (1 giga = 1 billion).

By improving efficiency of the form and position of three electrodes, designed to emit and accelerate electrons, through redesigning, Mitsubishi was able to ensure the maximum of 40 amperes at 90 kV. Moreover, by focusing beams to a 0.3 mm diameter, the company has succeeded in devising the firing of large current electron beams which do not discharge even at high voltage.

The resonant cavity which transforms these electron beams into 120 GHz milli-waves, in the meantime, was placed in powerful magnetic fields of 45,000 Gauss created by a superconductive magnet; and, by obtaining a form matching the electronic gyration frequency, the company was able to devise a high-efficiency conversion of electronic energy into high-frequency energy.

This has produced 34 amp. electron beams when 92kV voltage was applied to the electron gun, achieving energy conversion efficiency of 32.5% and the gyrotron output of 1.02 MW.

At present, research, pursued from the standpoint of improved gyrotron output and longer output time, is showing progress. In the area of improved output, the United States has succeeded in generating 500kW in 2 seconds. In the area of longer output time, MIT in the United States has reported a 1.2MW output in 3 microseconds.

With the large-scale nuclear fusion experiment equipment, 20 or 30 MW high frequency is required for heating the plasma. In order to simplify the equipment configuration, a high-output gyrotron is sought. In view of this, after a 1.5 MW output has been realized, Mitsubishi Electric plans to improve and achieve a practical gyrotron capable of longer-hour output.

Sharp Corporation Develops Record High Output Red SC Laser

943FE0667D Tokyo NIHON KOGYO SHIMBUN Japanese 23 Mar 94 p 6

[Text] Sharp Corporation (president: Mr. Haruo Tsuji) has developed a red LD (semiconductor) laser with the world's largest light output of 95mW in the single lateral mode. The existing LD had the problem of crystalline degradation when light was absorbed at the edge of lasers whenever an attempt was made to obtain a large output. Sharp has solved this problem by developing an "end window growth technology" designed to construct a transparent window structure. This has opened the way to the development of the next generation of light source, raising the density of optical disks to 1.3 times as high.

At present, the light source used for "read/write data" is infrared lasers with wavelength of 780nm (1 nm = one-billionth meter). For the next generation of multimedia optic disks designed to record images, voices, and characters at higher density and speed, a 680nm wavelength red LD is regarded as most promising.

However, the range of the existing practical red LD's output is 30 - 50 mW, and even the laboratory level LD output barely reaches 200 mW. Any attempt in the past had resulted in the degradation of lasers brought about by the absorption of light, making its use as a light source of the next generation of optic disks difficult.

With the newly-developed product, Sharp has succeeded in fabricating an aluminum-gallium-indium-phosphorus crystalline window on the edge of a laser using its own MOCVD ([organometallic crystal vapor phase growth]) method. Since the crystals do not absorb light, the company was able to achieve high output of 295mW without occurrence of degradation of lasers. Moreover, the company is able to lengthen the product's effective life as LD to tenfold.

Tohoku University Uses STM to Explain Etching Mechanism

943FE0669A Tokyo NIKKAN KOGYO SHIMBUN in Japanese 7 Apr 94 p 5

[Text] Jointly with Professor Pickering and his associates at the University of Pennsylvania, Professor Toshio Sakurai and Assistant Professor Tomihiro Hashizume of Tohoku University's Metal Research Laboratory has succeeded for the first time in explaining the [etching] mechanism using STM (scanning tunnel microscope). Based on their observation of the way in which BTA (benzotriazole), a typical copper corrosion inhibitor, and copper are polymerized after being adsorbed to the copper oxide surface, the research team explained the corrosion inhibiting mechanism in terms of atoms. This will lead not only to more advanced development of corrosion inhibitors but also will usher the era of the atomic level observation of actual complex systems through use of the STM, which, this breakthrough, could observe only a simple and ideal form of specimen.

The BTA used in the observation was a white microcrystal, deposited in an ultra-high vacuum. Using this methodological characteristic, observation was made of the BTA, formed inside the STM ultra-high vacuum at the time of vacuum deposition of molecular beams on a clean copper surface and oxide copper surface known for its strong corrosion resistance, using an FI (field ion) type high-performance STM.

Professor Pickering participating in this joint research specializes in the electric chemical field, including etching, from the outset. As a member of this joint research team, he studied in detail the polymerization process of BTA and the state of electrons on the copper surface, explaining BTA's corrosion inhibiting mechanism on both copper and oxide copper surfaces.

According to the explanation, BTA easily moves on a clean copper surface and is adsorbed to the tip of an atomic step systematically arranging itself in relation to atoms on the copper surface. It was observed subsequently that string-like molecular rows were formed on the second layer, with these molecules being chemically bonded with one another and polymerized.

As for the way in which BTA is adsorbed to the oxide copper (which plays an important role in actual use because of its corrosion-resistant property), it was found that the concentration of BTA at the copper atom step will lead to polymerization. It became clear for the first time that, although the BTA and oxide copper do not form a strong bond, a polymerized BTA film serves as a tough coating, protecting a copper surface from corrosion.

Since around 1950, BTA has served as typical corrosion inhibitors for copper and used in building air conditioners' circulating water pipes, as well as automobiles' water cooling copper pipes. However, its corrosion inhibiting mechanism had never been explained fully. What has been accomplished by the U.S.-Japan university research team this time is to observe complex BTA etching mechanisms at an atomic level using a high-performance FI-STM.

The result of its research effort goes beyond the observation of BTA. The team claims that with the existence of certain conditions, viz., the deposition of a single molecule and the polymerization on a surface, the observation of complex organic molecular system becomes possible with the use of STM, thus ushering a new era in the application of STM.

STA Improves Transmission Electron Microscope System

943FE0669C Tokyo NIKKEI SANGYO SHIMBUN in Japanese 19 Apr 94 p 5

[Text] Science and Technology Agency (STA)'s National Research Institute for Metals (NRIM) has developed a system designed to improve the observation accuracy of transmission electron microscopes (TEM). The system converts electrons transmitted through materials into light using a fluorescent device and measures its intensity with the CCD (charge coupled device) camera. In comparison with the existing method which sensitizes a film, the contrast produced by the new method is said to be 40 times better. Another characteristic of the new system is that, since it sends CCD camera data directly to its computer for processing, realtime observation is feasible. The system also can capture detailed atomic arrangements of metallic materials. NRIM is considering the use of system in elucidating superconductive mechanisms.

The system, installed directly below the electronic microscope, is capable of measuring extremely low-intensity electrons transmitted through materials. The transmitted electrons, first of all, are converted into lights by a scintillator (fluorescent material) made of YAG (yttrium-aluminum-garnet). After passing through two or three 10cm-long optic fibers in a bundle—during which time X rays (noise) are eliminated—the light reaches CCD.

The CCD consisting of 512 pixels, length by width, covers an area of 2cm diameter, slightly larger than the image received by the scintillator. The data thus obtained will be processed by the computer and displayed instantly on a screen.

Since diffracted images of electrons produced by the existing method lacked strong contrast, it was not possible to obtain detailed information. The use of CCD with excellent photographic sensitivity in the new method is said to provide the system with the 40 to 60 times greater ability to capture the contrast of light and darkness.

In experiments, iron-nickel alloyed thin film was examined. After the alloy was heat-processed at the temperature of 700°C, researchers observed materials deposited on the surface and found metal atoms to be slightly in disarray, a phenomenon which was not possible to observe with the existing method.

In crystal forming materials, including superconducting materials, atoms are arranged with a high degree of regularity. Recent research revealed, however, that slight disturbance to this systematic arrangement will greatly influence the properties of materials. For this reason, a technology capable of observing the slight disturbance in atomic arrangement has been sought. NRIM's first research group's chief research officer, Takayoshi Kimoto, said, "Using the new observation system, we wish to continue working to explain superconductive mechanisms."

Optical Modules for 10 Gb/s Optical Transmission Systems

94FE0493A Tokyo OKI DENKI KENKYU KAIHATSU in Japanese Vol 61 No 1, Jan 94 pp 53-58

[Article by Takashi Ushikubo, Kiyoshi Nagai, Ryozo Furukawa, and Shunji Sakai]

[Text]

Abstract

We developed an optico-electric conversion (O/E) module for 10 Gb/s optical transmission systems. An O/E module is made up of a PIN photodiode (PIN-PD), a preamp, and an optical system for irradiating the PIN-PD with a light signal from optical fiber. The O/E module prototype achieves transimpedance of 54 dBΩ, frequency band of 15 GHz, and mean input equivalent noise current Hz divided by 7 Pa low noise/wide band characteristics. We conducted 10 Gb/s transmission tests, achieved good eye patterns and minimum reception power -18 dBm (symbolic error rate: 10^{-9}), demonstrating that the module can be used for 10 Gb/s optical transmission systems.

In this article, we discuss the design of the PIN-PD and preamp, and of the O/E module in which they are used, as well as the characteristics obtained and the results of the 10 Gb/s transmission tests.

1. Introduction

As the informational society rapidly gains force, higher-capacity, super-fast optical transmission systems are being demanded, and a lot of R&D is being done on 10 Gb/s optical transmission systems and system components oriented toward the broadband integrated service digital network (B-ISDN).[1,2] The electro-optical (E/O) and optico-electric (O/E) conversion units in these systems involve high-performance optical devices and ICs. In order to prevent characteristic deterioration caused during mounting, there is a demand for modular technology which mounts the optical devices, IC's, optical fiber, and lenses, etc., all in the same package.[3,4]

We have already developed a PIN photodiode (PIN-PD) that operates at 10 GHz and above, and a GaAs preamp IC, and are working on the development of E/O and O/E modules that combine these.[5-8]

In this article we discuss an O/E module for use with a 10 Gb/s optical transmission system that achieves wideband and low-noise performance. More particularly, we discuss the design of the PIN-PD, preamp, and O/E module which uses these, as well as the results of 10 Gb/s transmission tests using the said O/E module.

2. Design of O/E Module for 10 Gb/s Optical Transmission

2.1 Module Structure

In Figure 1 the structure of the O/E module is depicted. The module is made up of the PIN-PD, preamp, and

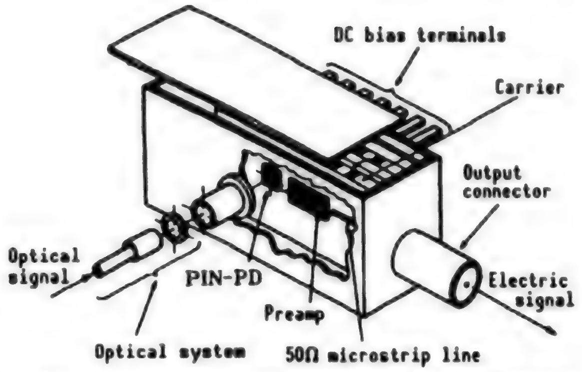

Figure 1. Schematic Configuration of the O/E Module

optical system for irradiating the PIN-PD with an optical signal from optical fiber. Single mode fiber is used for the optical fiber, and a connector is used for the electrical signal output that can be used up to and including high frequencies.

In Figure 2 is given the equivalent circuit diagram for the O/E module.[7] In designing the module, we conducted simulations, taking into consideration the parasitic capacitance and inductance which are factors when mounting the preamp and the PIN-PD. For the PIN-PD equivalent circuit we used a voltage-controlled current source. the noise of the O/E module is determined more or less by the feedback resistance and heat noise of the FET in the first stage of the preamp. In reducing this noise, it is effective to cause the FET gate capacitance in the first-stage FET to coincide with the equivalent capacitance that is connected to the preamp input (i.e. the sum of the PIN-PD element capacitance and the wiring capacitance resulting from mounting).[9,10] Meanwhile, in order to enhance the frequency characteristics, it is necessary to reduce the FET gate capacitance and the inductance which results from installing the bonding wires etc. For this reason, we designed the mounting structure so as to minimize the capacitance and inductance resulting from mounting, while also reducing the PIN-PD element capacitance.

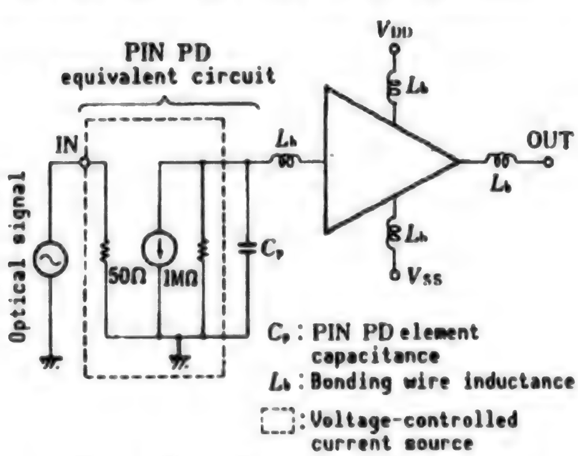

Figure 2. Equivalent Circuit of the O/E Module

In order to reduce the mounting-related capacitance and inductance, for the PIN-PD and preamp we used bear-chip mounting on a carrier formed from a copper/tungsten base on a ceramic board, connecting the two with bonding wire. The preamp was attached to the Cu/W base in order to improve heat dissipation, and the output thereof was connected to the connector using a strip line having a characteristic impedance of 50 Ω. A spherical lens was used to optically join the optical fiber to the PIN-PD. The end surface of the optical fiber was slant-polished to prevent reflected return light.

2.2 PIN Photodiode (PIN-PD)

In Figure 3 is depicted the PIN-PD element structure. This PIN-PD is a surface irradiation type in which the signal light is directed from the p region side to the p-n junction. The structure is such that there is a ring-shaped p-side electrode on the p region surface in the vicinity of the irradiation area (light receiving window), and an n-side electrode on the back surface of the element. The wafer from which the element is made has a triple-layer structure, with an n-InP buffer layer, n-$In_{0.47}Ga_{0.57}As$ photo-absorbing layer, and n-InP window layer gas-phase grown on the n-InP substrate. The p region is fabricated zinc heat diffusion. For the p-side and n-side electrodes, we used ohmic electrodes of AuZn and AuGeNi, respectively, and used TiPtAu and Au plating on the interconnect electrodes.

The operating speed of the PIN-PD is determined by the element capacitance (which is the sum of the p-n junction capacitance andelectrode capacitance), and the time required for the carrier to pas through the photo-absorbing layer. This being so, we optimized the thickness of the light receiving layer and the light receiving window diameter (light receiving diameter) which determine(s) the area of the p-n junction.

In Figure 4 we have plotted the results of calculations made on the relationship between the photo-absorbing layer thickness and frequency characteristics (in the -3 dB

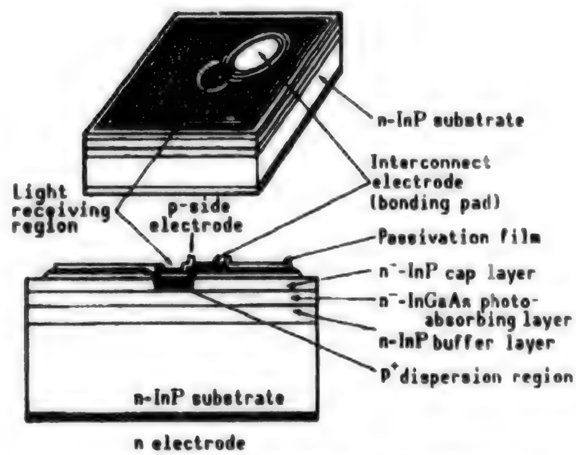

Figure 3. Device Structure of PIN Photodiode

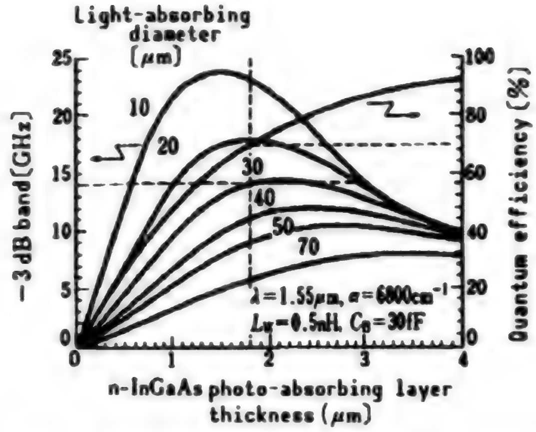

Figure 4. Dependence of Absorbed Layer Thickness on -3 dB Bandwidth and Collection Efficiency

band), and the quantum efficiency, taking the light receiving diameter as a parameter.[11] The thickness of the photo-absorbing layer at which the -3 dB band maximizes becomes thinner as the light receiving diameter becomes smaller. The quantum efficiency, however, increases as the thickness of the photo-absorbing layer increases. From the results of these calculations, we see that, in order to secure 10 Gb/s operation, when we allow some leeway and make the band 14 GHz or higher and the quantum efficiency 70% or higher, we need a photo-absorbing layer thickness of 1.8 μm or greater and a light receiving diameter of 30 μm or less.

Next, by lowering the ohmic resistance of the p-side electrode, we made the p-side electrode very small and lowered the electrode capacitance.[12] In Table 1, we give actually measured values for the p-n junction capacitance and electrode capacitance with the light receiving diameter at 20 μm and 30 μm. By making the light receiving diameter small, we were able to reduce the element capacitance (p-n junction capacitance plus electrode capacitance).

Meanwhile, The optical system positioning leeway (tolerance) for putting the output light from the optical fiber into the light receiving window PIN-PD becomes smaller as the light receiving diameter is made more minute, which also results in more exacting requirements for mounting the optical components. Considering these factors, we used a PIN-PD having a light receiving diameter of 20 μm and photo-absorption layer thickness of 1.8 μm in the O/E module. In Figure 5 we plot the PIN-PD frequency characteristics. The reverse bias voltage at the time the measurements were made was 10 V. The -3 dB frequency band is at 16 GHz, and we obtained characteristics about the same as the calculated values. The other PIN-PD characteristics at this time were dark current of 100 pA, a quantum efficiency of 68% (wavelength 1.55 μm), and an element capacitance of 0.25 pF.

Table 1. PIN-PD Element Capacitance vs Light Receiving Diameter (Measured Values)

	Light receiving diameter (μm)	
	20	30
p-n junction capacitance (fF)	98	150
Electrode capacitance (fF)	150	150

2.3 Preamp

In Figure 6 we give the circuit diagram for the preamplifier. This is a directly-connected transformer-impedance type of amplifier. We useInGaAs/GaAs type MESFETs having a gate length of 0.2 μm in this preamp. The gate lengths of these FETs were made 0.2 μm or lower in order to improve the cut-off frequency, and the mushroom gate process was employed to reduce the gate resistance.[13] The maximum cut-off frequency of the FETs is about 65 GHz when the gate width is 150 μm.

In Photo 1 is shown the preamp chip, which has the dimensions 1.3 x 2.35 mm. For the first-stage FET (Q_1 in Figure 6) we used a gate width of 180 μm in order to match the PIN-PD element capacitance. In order to obtain bandwidth characteristics above 10 GHz, we used cascade-connected FETs, and optimized the peaking inductor and the feedback resistance values.

3. Optical System Study

We used a one-spherical-lens optical system in the O/E module. In order to effect an airtight seal between the

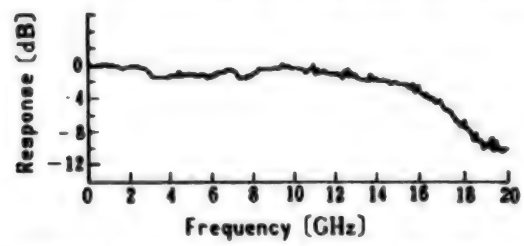

Figure 5. PIN Photodiode Frequency Response

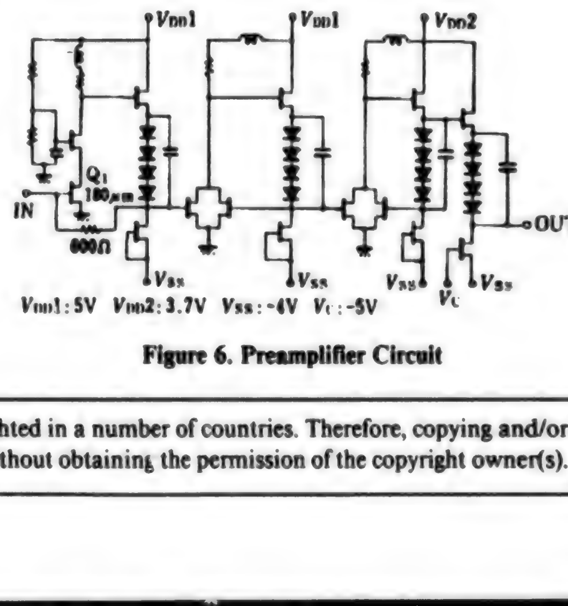

Figure 6. Preamplifier Circuit

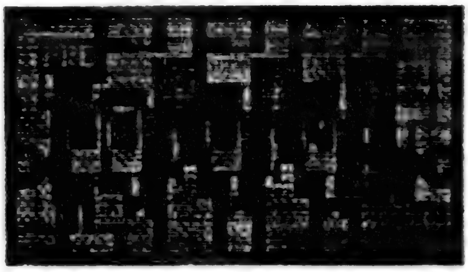

Photo 1. Microphotograph of the Preamplifier

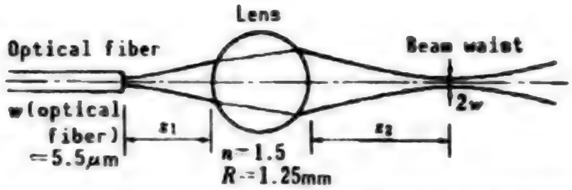

Figure 7. Schematic Diagram of the Optical Coupling

PIN-PD and spherical lens (needed to insure high reliability), it is necessary to make the distance between them on the order of several mm. We therefore optimized the optical system by conducting gaussian beam approximation simulations.

In Figure 7 we give a coordinate system for this. For the spherical lens we used BK7 material and a diameter of 2.5mm. If we take z_1 as the distance from the optical fiber to the spherical lens end surface, z_2 as the distance from the spherical lens end surface to the beam waist where the beam from the optical fiber is collected by the spherical lens, and w as the spot size at the beam waist (i.e., the half width at which the light power is $1/e^2$), then the relationship between z_1, z_2, and w is as plotted in Figure 8. Note, however, that we made the optical fiber spot size 5.5 μm.

From Figure 8 we can see that we need only increase z_1 in order to narrow the beam, but then z_2 also becomes smaller. And if we make z_1 larger, the projection from the module becomes larger, making the overall module larger. In view of these things, we made z_2 about 3mm and z_1 2mm. The value of w is then around 7 μm.

Next we studied the optical positioning leeway (tolerance) between the optical system and the PIN-PD. If we assume that a gaussian beam is directed into the light receiving window, then we can plot the relationship between the gaussian beam position and coupling efficiency as in Figure 9. When the spot size is 7 μm, we obtain a maximum coupling efficiency of 98%. We find that the tolerance is a half valueof 4.5 μm when the coupling efficiency is 90%.

In order to verify the simulation results, we conducted coupling tests using a spherical lens and PIN-PD. In Figure 10 we have plotted the relative values when standardizing the change in the coupling efficiency (measured values) at maximum. The tolerance half value is μm when at 90% from the maximum value, which agrees well with the computed value.

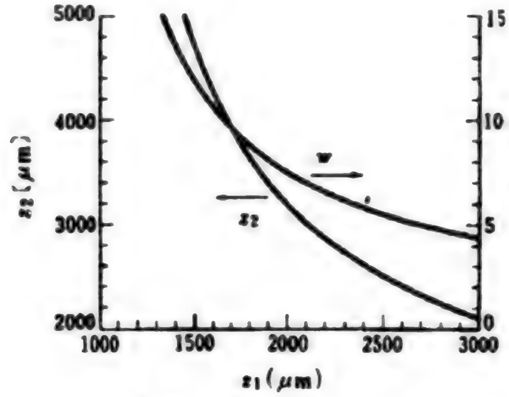

Figure 8. Dependence of z_1 on z_2 and w

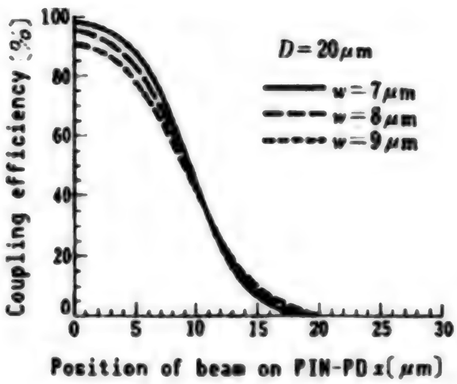

Figure 9. Dependence of Photodiode x Position on Coupling Efficiency (Simulated)

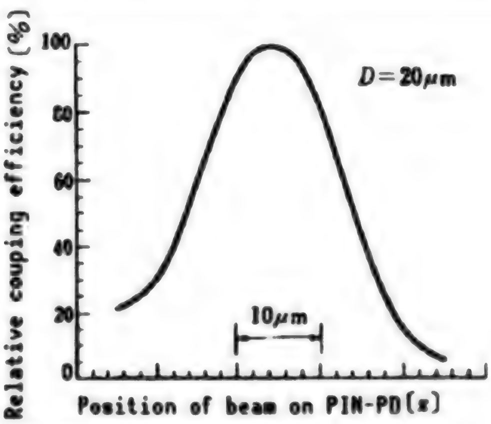

Figure 10. Dependence of Photodiode x Position on Relative Coupling Efficiency (Measured)

4. O/E Module Prototyping

Using the PIN-PD and preamp described above, we prototype an O/E module. In mounting the PIN-PD, we wanted to make the wiring-induced inductance as low as possible, so we attached the PIN-PD to the bias line of a ceramic board and connected the preamp with wire bonding. This bias line broadens the width and lowers the impedance from the package terminal(s).

Meanwhile, when the line width is broad, resonance develops in the width direction near the PIN-PD that is the end of the line, and this affects the frequency characteristics. This being so, we mounted a small-capacitance bypass capacitor on either side of the bias line to prevent resonance in the lateral direction in the bias line.[14]

We installed the optical components by means of spot welding using a YAG laser. The dimensions of the O/E module, excluding the protrusion, are 25 x 14 x 13 mm.

5. Test Results, Analysis

5.1 Frequency, Noise Characteristics

We now discuss the results of our evaluation of the prototype O/E module.

In Figure 11 we have graphed the transimpedance and S-parameter S_{22} frequency characteristics. The transimpedance is 54 dBΩ, and a 15 GHz band was obtained. The value of S_{22} is below 10 dB up to 10 GHz, and is -8 dB even at 15 GHz.

We measured the noise characteristics with a spectroanalyzer, connecting a high-gain amplifier to the final stage of the O/E module. In Figure 12 we have graphed the frequency dependence of the input equivalent noise current of the O/E module. From this we obtained the low value of Hz divided by 7.0 pA for the mean input equivalent noise current.

5.2 Transmission Tests

We conducted 10 Gb/s transmission tests using the O/E module prototype. The test setup is diagrammed in Figure 13. In the transmitter unit, continuously generated (CW) light from a DFB laser having an oscillation wavelength of 1.55 µm is NRZ modulated at 10 Gb/s (PN: 2^7-1, mark ratio: 1/2) using a Mach-Zehnder type $LiNbO_3$ photomodulator, then amplified with an erbium-doped optical fiber amp (EDFA), using an optical output of approximately +12 dBm. For the transmission route we used 40 km of ordinary dispersion fiber. This corresponds to a total dispersion amount of 658 ps/mm for a wavelength of 1.55 µm. In the receiver unit, after passing through a variable photo-attenuator, O/E conversion is done in the O/E module. After amplifying the output signal from the O/E module, the signal passes through an EXOR-based timing extracting circuit and a D-type flip-flop based identification circuit, and is then evaluated by a sampling oscilloscope and error rate detector.

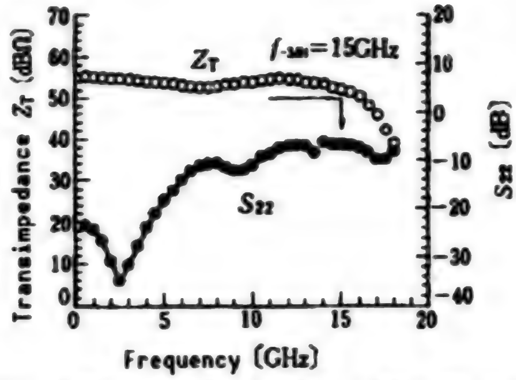

Figure 11. Frequency Characteristics of Transimpedance Z_T and S_{22} of O/E Module

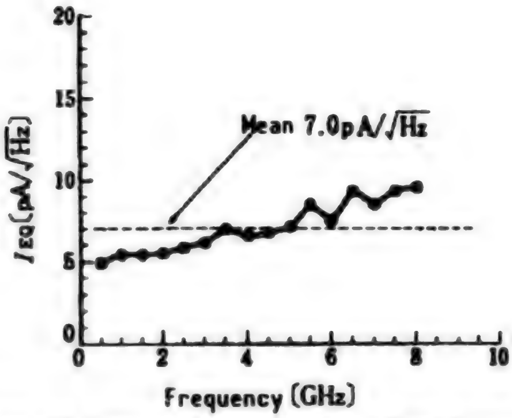

Figure 12. Frequency Characteristics of Input Equivalent NoiseCurrent I_{EQ} of the Optical Receiver

In Figure 14 is shown the eye patterns after transmission. A good aperture is indicated in the post-transmission eye patterns. Figure 15 shows a plot of the bit error rate characteristics after transmission. The minimum reception power which will satisfy a bit error rate of 10^{-9} is -18 dBm.

6. Concluding Comments

We developed an O/E module for use in 10 Gb/s optical transmission systems. The prototype O/E module achieved transimpedance of 54 dBΩ, a frequency band of 15 GHz, and low-noise wide-band characteristics with a mean input equivalent noise current of Hz divided by 7.0 pA. We conducted 10 Gb/s transmission tests, confirming the achievement of good eye aperture and a minimum reception power of -18 dBm (bit error rate: 10^{-9}), demonstrating the applicability of the module in a 10 Gb/s optical communications system.

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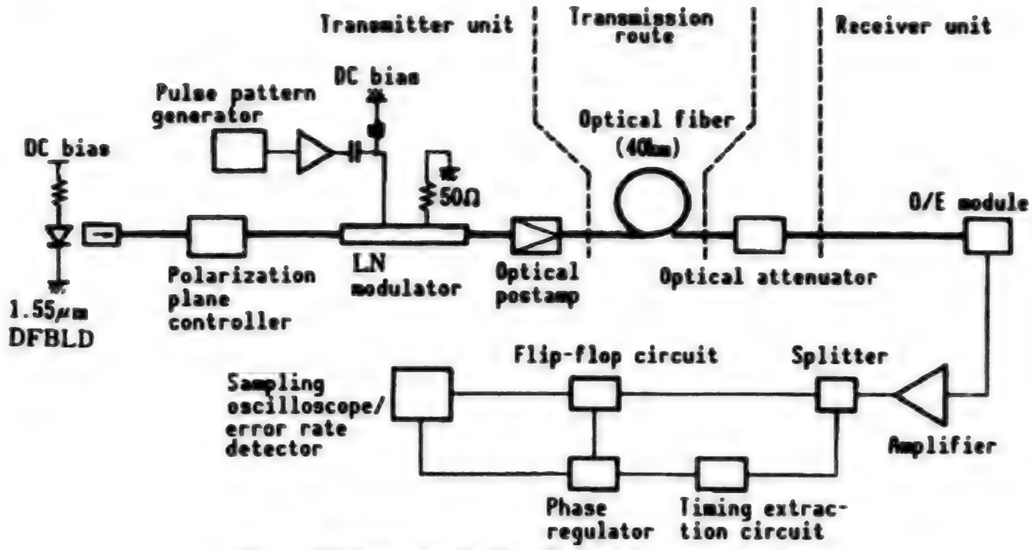

Figure 13. Setup for 10 Gb/s Optical Transmission Tests

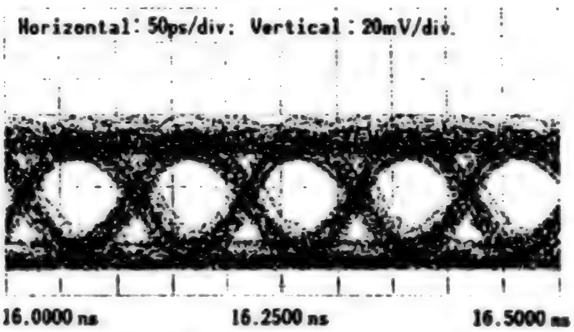

Figure 14. Output Eye Diagram at 10 Gb/s

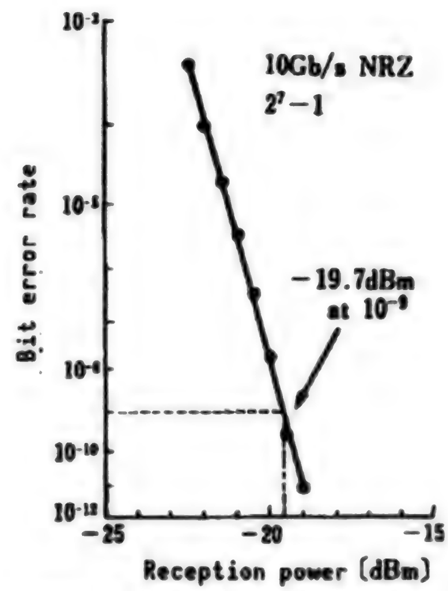

Figure 15. Bit Error Rate Characteristics

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Development of Optical Devices for Optical Fiber Amplifier

94FE0493B Tokyo OKI DENKI KENKYU KAIHATSU in Japanese Vol 61 No 1, Jan 94 pp 49-52

[Article by Katsuyoshi Naito, Ikuo Fukuzaki, and Hideyuki Tanaka]

[Text]

Abstract

In order to improve the performance of an optical fiber amplifier, we increased the output and reduced the power consumption of an LD module for 1.48 μm optical amplifier excitation and developed composite passive optical compo-..ents to reduce loss in optical components. We here report on various aspects of the technological development of these devices, and on the results of our evaluations.

1. Introduction

Optical fiber amplifiers exhibit good characteristics such as high gain and low noise, and progress is being made toward applications in long-range high-volume optical transmission, optical subscriber system transmission, and optical cable TV.[1,2]

In order to develop practical optical fiber amplifier units, it goes without saying that we need outstanding amplification and noise characteristics. But we also need compactness and low power consumption. And, in order to achieve low noise characteristics, we must employ optical circuit components that exhibit little insertion loss. As to making the units compact, they would have to be thin in order to be compatible with the high-density mountings made in current standard systems.[3] As to making them lower in power consumption, it is desirable, from the standpoint of system economics, that they be usable under self-cooling conditions.

In order to develop an optical fiber amplifier that would satisfy all these conditions, we developed a 1.48 μm LD module carrying an MQW-LD (semiconductor laser) element for the purpose of raising the output and lowering the power consumption, for use as a light source for exciting erbium-doped optical fiber. We also developed a composite optical circuit module, based on the single-package beam coupling approach, in the interest of low insertion loss and compactness.

In this article we discuss the development of these optical components and report on the characteristics of optical fiber amplifiers in which they are loaded.

2. Optical Fiber Amplifier Configuration

In Figure 1 the configuration of the erbium-doped optical fiber amplifier (EDFA) is diagrammed. In Table 1 the characteristics of the amplifier are listed.[4]

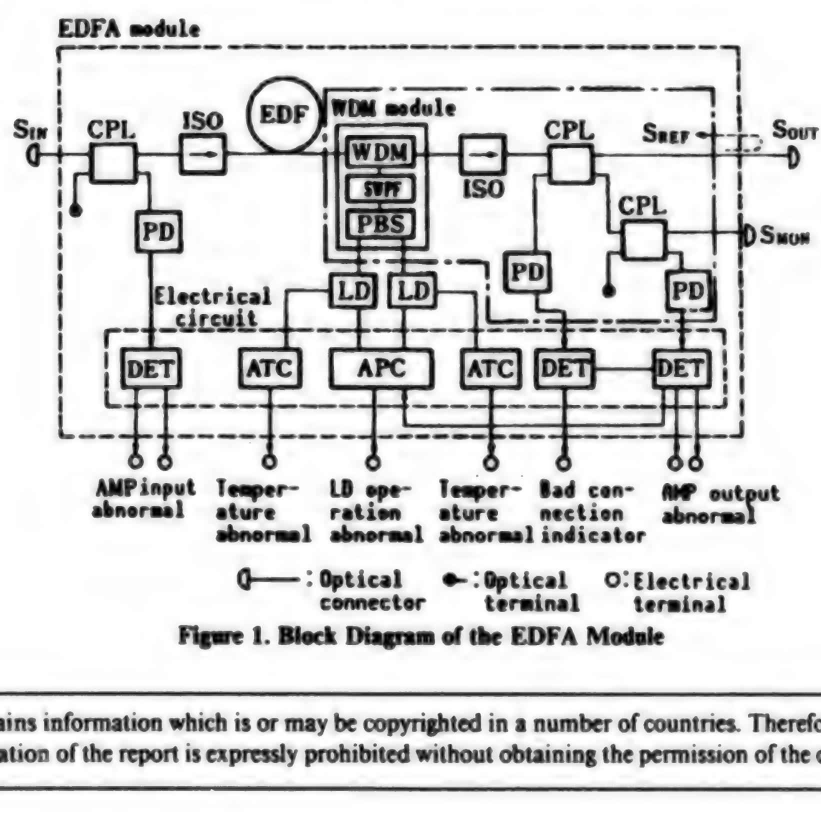

Figure 1. Block Diagram of the EDFA Module

Table 1. Characteristics of EDFA Module

Saturated optical output	+13 to +16 dBm (@1.55 μ band)
Small signal gain	≥30 dB
Noise index	≤8 dB (optical input ≤-10 dBm)
Excitation light source	1480 nm-LD, APC/ATC control
EDF	Doped with both Er and Al MFD @ 1.55 μm: 4.5 μm Er concentration: Approx. 900 ppm (weight) Al concentration: Approx. 15,000 ppm (weight)
Input/output fiber	1.3 μm zero-dispersion SMF
Monitor circuit	Input signal monitor, output signal monitor output connector reflection monitor (bad connection detection)
Power supply	+5 V, single unit
Outer dimensions	210 (L) x 170 (W) x 12.5 (H) (mm)
Weight	Approx. 500 g

Based on a WDM module that combines the polarization synthesizing function (PBS) and wavelength synthesizing function (WDM), the configuration is such that the excitation light from two high-powered 1.48 μm LD modules can be synthesized in the EDG with low loss. The LD module for excitation is made so that the excitation light output can be maintained stably by means of an output control circuit (APC) and a temperature control circuit (ATC). On the input and output sides, respectively, the input signal light (S_{IN}) that is split at the fiber optical coupler (CPL), the output signal light (S_{OUT}), and the output connector reflected light (S_{REF}) are monitored with a light reception module (PD), and, by sending the monitor signals to the monitor control system with a detection circuit (DET), it is possible to control the optical amplification. All of the devices are interconnected using optical fiber fusion. Connection loss and reflectance were reduced by minimizing the number of connection points. In Table 2 are given the mean insertion loss values for each part.

Table 2. Insertion Loss (Average)

	Light path	Insertion loss
Signal system @ 1.554 μm	Front stage (CPL + ISO) Back stage (WDM + ISO + CPL)	1 dB 2 dB
Excitation light system @ 1.48 μm	PBS + SWPF + WDM	0.9 dB

Next we discuss the development of the necessary components for developing the EDFA noted above.

3. LD Module for Optical Amplifier Excitation

3.1 Design Conditions

We kept the following points in mind in designing the LD module for use in high-powered optical amplifiers.

(1) The LD element should have an optical output of 100 mW or greater.

(2) The optical fiber coupling efficiency should be high.

(3) The LD element and module must exhibit good heat dissipation.

(4) It should be possible to effect polarization synthesis using polarization plane preserving fiber.

3.2 Configuration

In Figure 2 is given a cross-sectional view of the internal structure of the OPD1404LD module which we developed.

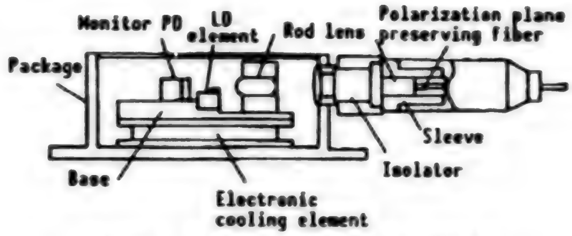

Figure 2. Structure of OPD1404 Module

The element used is a 1.48 μm LD element having an MQW structure. After mounting this on the same base with the monitor PD and chip thermistor, we secured it above an electronic cooling element with solder. The LD light is converted into a gently converging beam by the internal rod lens, and is then led out of the package via a glass window that is hermetically sealed in the side of the package. Outside the package, a polarization plane preserving fiber having a rod lens bonded to it to serve as the second lens for the said LD light was optically adjusted via a sleeve and then fixed in place. We used YAG laser welding to secure all of these optical components. We ground the end of the polarization plane preserving fiber to give it an 8° slant to prevent reflected light from returning to the LD. We metallized the side surfaces of the internal lens to improve its reliability, and then secured it to a holder with high-melting-point solder.

For the LD module package we employed a 14-pin butterfly package having a wide heat dissipation area and dimensions of 36.5 (L) x 15.0 (W) x 8.3 (H) mm. In order to enhance the heat dissipation characteristics, we used copper-tungsten (Cu-W) on the bottom of the package and aluminum nitride (AlN) on the upper and lower substrates on the electronic cooling element, fixing these in place with high-melting-point solder.

3.3 Characteristics

In Table 3 we give the main characteristics of the OPD1404LD module. And in Figure 3 we plot the I-L and I-I_m characteristics at an ambient temperature (T_a) of 25°C. We obtained high output, achieving the targeted value of 100 mW for the optical fiber output. In Figure 4 we plot the cooling characteristics of the OPD1404LD module. When we perform ATC control inside the

package, maintaining an LD element unit temperature (T_{LD}) of 25°C, and perform APC control using the built-in monitor PD, we confirmed that we could stably maintain a temperature differential ($\Delta T = T_a - T_{LD}$) of 40°C, up to an ambient temperature of 65°C. The cooler power consumption at that time was a low 2.5 W. And, as indicated by the temperature cycle test results plotted in Figure 5, we obtained highly reliable optical output by exploiting such metal attachment techniques as YAG laser welding.

Table 3 Characteristics of OPD1404LD Module (TLD = 25°C, TLD: Temperature of laser diode)

Item	Min.	Typ.	Max.	Units
Threshold current (I_{th})		35	65	mA
Operating current (I_{op})		600		mA
Optical fiber output (P_f)	90	100		mW
Forward voltage (V_f)		1.75	2.0	V
Center wavelength (λc)	1470	1480	1490	nm
Spectrum width (Δ λ)		10	20	nm
Polarization crosstalk (P_r)	15	20		dB
Monitor current (I_m)	0.05	0.30	1.0	mA
Cooler current (I_c)		3	3.5	A
Cooler voltage (V_c) Tc	0.8	1.0	V	
Thermistor resistance (R_{th})		10		kΩ

4. Complex Optical Circuit Module

We developed and prototyped a complex optical circuit module in which we integrated the optical circuit components positioned after the EDF of the back excitation EDFA using 1.48 µm excitation light (inside short-long dashed lines in Figure 1).

In designing this module, we established the following functions and target characteristics.

4.1 Design Conditions

(1) Signal light and excitation light wavelength synthesis (back excitation)

(2) 1.48 µm excitation light polarization synthesis

(3) Light oscillation prevention at excitation light port

(4) Built-in optical isolator to prevent light oscillation in signal system

(5) Optical monitor for output signal light

(6) Built-in light reception element for gain control

(7) Built-in light reception element for signal light output light bad connection detection

(8) Signal system insertion loss: ≤1.5 dB

(9) Signal system polarized light dependence loss fluctuation: ≤0.2 dB

(10) Signal system reverse insertion loss: ≥50 dB

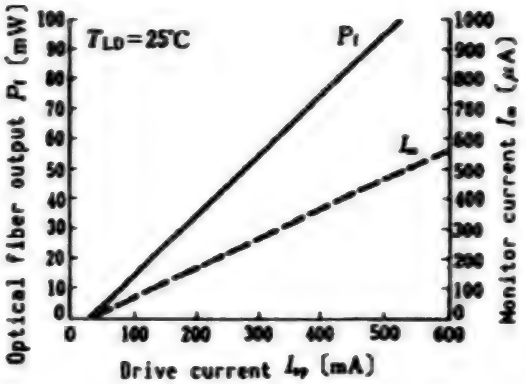

Figure 3. OPD1404LD Module I-L, I-I_m Characteristics

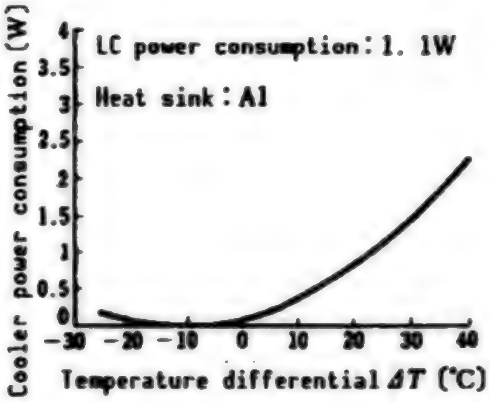

Figure 4. Cooling Characteristics of OPD1404LD Module

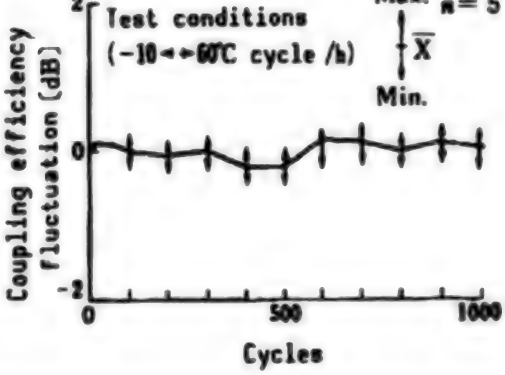

Figure 5. OPD1404LD Module Temperature Cycle Test Results

(11) Excitation light insertion loss: ≤1 dB

4.2 Configuration

In Figure 5 the configuration of the optical circuit in the complex optical circuit module is diagrammed. We achieved compactness and lossminimization by positioning the functional element(s) in(side) the parallel beam(s). The parallel beams are configured with a spherical lens and a slant-ground optical fiber in which an antireflection film is deposited on the end surface. The optical fiber used in the input/output unit has a single-mode optical fiber core at the S_{IN}, S_{OUT}, and S_{MON} ports and a polarization plane preserving fiber core at the P1 and P2 ports.

4.2.1 Excitation Light Polarization Synthesis

By means of the wavelength synthesis element (WDM) wavelength synthesis is done for the 1.55 μm signal light and 1.48 μm excitation light, and the excitation light is input to the EDF in the back excitation mode. In order to obtain high-output excitation light, two 1.48 μm excitation beams having mutually perpendicular polarization planes are polarization-synthesized by a polarization synthesis element (PBS). Should the signal light leak through to the excitation light side, an optical filter element (SWPF) is positioned after the polarization synthesis in order to remove the signal light portion and thereby suppress oscillation.

Multilayer dielectric films are used in the wavelength synthesis element (WDM), polarization synthesis element (PBS), and filter element (SWPF). The excitation light input to the P1 and P2 ports is converted to (a) parallel beam(s), is polarization-synthesized by the PBS, passes through the SWPF, is wavelength synthesized by the WDM, and is output from the S_{IN} port.[6]

4.2.2 Monitor Function

For the output signal light monitor and gain control and bad optical connection detection at the signal light output port(s), we used light reception elements PD1 and PD2 and light splitter elements BS1 and BS2 formed with multilayer dielectric films. The signal light input to the S_{IN} port is converted to (a) parallel beam(s), which then pass(es) through the WDM, ISO, and BS1 and is/are output from the S_{OUT} port. The signal light that passes through BS2 is input to PD1 and converted to an electrical signal. In the event that the optical connector at the S_{OUT} port comes loose, the light reflected from the optical fiber end surface is converted to (a) parallel beam(s), split-reflected by BS1, input to PD2, and converted to (an) electrical signal(s).

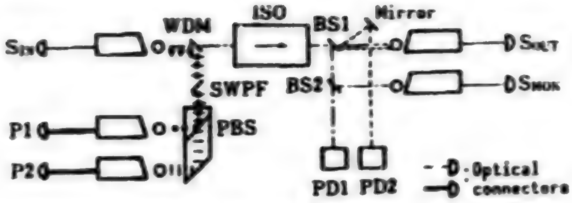

Figure 6. Configuration of Complex Optical Circuit Module

4.3 Characteristics

We note the characteristics of the prototype complex optical circuit module in Table 4. The signal system insertion loss was 1.3 dB (inclusive of the passage loss through one signal light input light connector and the WDM, ISO, and BS1, while the polarized light dependence loss fluctuation was 0.1 dB, which are good values. The signal light reverse insertion loss (isolation) was 59 dB, which is also good.

Table 4. Characteristics of Optical Circuit Module (Average)

Item	Insertion loss (dB)		Polarized light dependence (dB)	Isolation (dB)	Internal reflection attenuation (dB)
Light route	1.554 μm	1.480 μm	1.554 μm	1.554 μm	1.554 μm
S_{IN}→S_{OUT}	1.3	—	0.11	59.2	59.5
P1,P2→S_{IN}	—	0.9	—	62.5	58.0

The passive optical components that make up the optical I/O ports and optical circuitry were all welded to the frame using a YAG laser.

The dimensions of the main module unit are a compact 68(L) x 40(W) x 8(H) mm.

5. Concluding Remarks

We developed a 1.48 μm LD module loaded with an MQW-LD element and having an optical fiber output of 100 mW. Nine functions, excluding the excitation LD positioned after the EDG, are configured as a complex optical circuit module based on the single-package beam coupling approach, and thereby achieved low signal system insertion loss (1.3 dB) and module compactness. We developed a back excitation type optical fiber amplifier using these optical components, achieving a roughly 80% down-scaling from conventional optical fiber amplifiers and 50% power consumption reduction.

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Low Distortion 1.3 Micron DFB Laser

94FE0493C Tokyo OKI DENKI KENKYU KAIHATSU in Japanese Vol 61 No 1, Jan 94 pp 25-28

[Article by Takashi Tsubota, Takashi Yoshida, and Yoji Hosoi]

[Text]

Abstract

With the growth of mobile communications, there is a movement toward the use of optical communication modes in microcell systems and cable TV systems. With the modulation modes used in these systems, mutual modulation distortion becomes a parameter which has a large impact on the system. We developed a distributed feedback (DFB) laser for use as a light source in these systems. We obtained good third inter-modulation distortion characteristics by employing a new element structure and optimization.

1. Introduction

In mobile communications systems, the narrow-band π/4 QPSKIM (π/4 quadruple phase shift keying intensity modulation) mode is employed. With this mode, however, third inter-modulation distortion (herein abbreviated IMD3) has a large impact on the system characteristics.

There are two major categories of factors which cause IMD3. One category is that IMD3 which is caused by the semiconductor laser that serves as the light source, having to do with interaction with the oscillation process during modulation. The other category is IMD3 which is caused by the optical transmission system, or, more specifically, by light reflection and scattering caused by such optical components as optical fiber and optical connectors.

There are limits to how well the IMD3 caused by these factors can be reduced with conventional element configurations.

We have now developed a distributed feedback (DFB) laser for use as a system light source, and have achieved optimization by employing the new multi-quantum well (herein abbreviated MQW) element structure.

In this article we discuss the simulations which we conducted on the various factors noted above, and the look at the results of our prototyping and evaluation of elements having an element structure designed on the basis of the said simulations.

2. Design

Let us first consider the IMD3 that is caused by a semiconductor laser. There are two types of IMD3, namely that which results from the interaction of three waves and that which results from the interaction between two waves. These two distortions are in a constant relationship, so that if we can determine one we can then calculate the other. Itturns out that the value of the three-wave distortion is the value of the two-wave distortion plus 6 dB. Accordingly, we evaluated IMD3 on the bases of two-wave distortion, which we can evaluate using a simple system.

We first assume two carriers having the frequencies ω1 and ω2, a semiconductor laser photon lifetime of τ_p, a carrier lifetime of τ_n, and a resonance frequency of τ_r. From the rate equation, the ratio between third inter-modulation distortion and the carrier (herein abbreviated IMD3/C) is then given by Formulas (1) and (2) below.

$$\begin{aligned}\frac{S_3}{S_1} = R(2\omega_1-\omega_2) * \frac{R(-\omega_2)^*}{R(\omega_1)} \\ \frac{i\omega_1+\frac{1}{\tau_n^*}}{-i\omega_2+\frac{1}{\tau_n}} \frac{-(2\omega_1-\omega_2)}{(\omega_r{}^2\tau_p)^2} \\ *(i\omega_r{}^2\tau_p + \omega_1 R(2\omega_1) \\ + (\omega_1-\omega_2)R(\omega_1-\omega_2))^* \left(\frac{S_1}{S_n}\right)^2\end{aligned} \tag{1}$$

$$IMD3/C = 20 \log\left(\frac{S_3}{S_1}\right) \tag{2}$$

$$R(\omega) = \left(i\omega+\frac{1}{\tau_n}\right)^* \frac{\tau_p}{1-\left(\frac{\omega}{\omega_r}\right)^2 + i\omega t_n^* \left(\frac{\tau_p}{\tau_n}+\frac{1}{(\tau_n\omega_r)^2}\right)}$$

where S_B is the DC photon density, S_1 the photon density resulting from frequency ω1, and S_3 the photon density resulting from the frequency 2ω1 - ω2

In Formula (1), S_1/S_B represents the optical modulation index (OMI). If we assume that the modulation frequency and the OMI are fixed, then IMD3/C becomes a function of ω_r, τ_p, and τ_n, the correlation between which parameters can be expressed by Formula (3) below.

$$\omega_r = \sqrt{1+\xi a \tau_p N_g^*} \; \frac{1}{\sqrt{\tau_p \tau_n}} * \sqrt{\frac{I_b - I_{th}}{I_{th}}} \quad (3)$$

From Formulas (1), (2), and (3) we can now plot the relationship between IMD3/C and the resonance frequency (ω_r) as in Figure 1. We can readily see from Figure 1 that increasing the resonance frequency is an effective way to improve IMD3/C. From Formula (3), we see that, in order to increase the resonance frequency, we need to increase the differential gain, reduce the photon and carrier lifetimes, and increase the bias level. We assumed a fixed bias level, however, we considered two methods for increasing the resonance frequency. One was to employ the MQW structure. The other (called "detuning") was to deliberately skew the gain-peak wavelength and the DFB laser oscillation wavelength. By using the MQW structure, the differential gain is increased by a factor of from 2 to 3, and by means of detuning -20 nm or so the resonance frequency is increased by a factor of approximately 1.5.[1,2]

Next we consider the IMD3/C that is caused by the optical transmission system. Such optical components as optical fiber and optical connectors are used in an optical transmission system, and one of the effects of such components is reflection. This reflection causes light interaction inside the fiber which produces IMD3.[3,4] If we assume two reflection points, and take R1 and R2 as the reflectance at each point, respectively, then IMD3/C is given by Formula (4) below.

$$IMD3/C = \frac{16 R_1 R_2}{OMI^2} * (J_1(Z) J_2(Z))^2 * \exp(-2\pi\Delta\nu\tau) \quad (4)$$

where J is a Bessel function, Δθ the line width, τ the delay time between the reflection points, Z is 2 m sin ($\pi\tau f m$), *m* the FM modulation index [= βΔI)/*fm*), β the FM modulation efficiency, *fm* the modulation frequency, and ΔI the modulation amplitude

The relationship between IMD3/C and the optical modulation index is plotted in Figures 2(a) and 2(b). In Figure 2(a) the FM modulation efficiency is taken as a parameter with the spectrum line width fixed at 10 MHz. In Figure 2(b) the spectrum line width is taken as a parameter with the FM modulation efficiency held constant at 100 MHz/mA. In order to reduce IMD3/C, we see from Figure 2(a) that we must reduce the FM modulation efficiency, and from Figure 2(b) that we must increase the spectrum line width. However, there is a positive correlation between these two parameters, such that if one is increased the other also increases. This being the case, in order to reduce IMD3/C we must find optimum values in view of the trade-off between the two parameters.

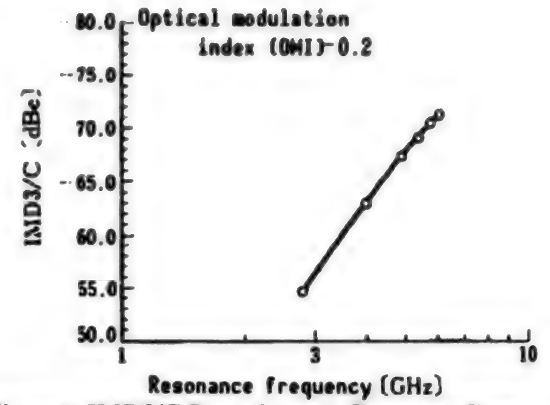

Figure 1. IMD3/C Dependence on Resonance Frequency

When we consider the DFB laser's wavelength characteristics and the reproducibility of the refraction grating fabrication process, the spectrum line width is limited at best to about 10 MHz. The IMD3/C is only improved about 7 dB by increasing the spectrum line width from 5 MHz to 10 MHz, resulting in an IMD3/C value of about -75 dBc. On the other hand, we can reduce the FM modulation efficiency to around 50 MHz/mA by reducing the effective carrier capture time by optimizing such conditions as the guide layer thickness. If we lower the FM modulation efficiency from 100 MHz/mA to 50 MHz/mA, the IMD3/C will be improved by about 10 dB, and we get an IMD3/C value of -85 dBc, which is good. Accordingly, lowering the FM modulation efficiency is an effective way to reduce IMD3/C. Under current conditions FM modulation efficiency values are running between 200 and 300 MHz/mA, so we targeted a value of 50 MHz/mA. We also targeted a spectrum line width of 10 MHz.

3. Element Prototyping, Evaluation

In Figure 3 the DFB laser element structure and energy levels are diagrammed. We adopted the BH (buried hetero) structure for current stricture and light containment. We conducted tests with a well number of 7 and an In GaAsP MQW structure having an oscillation wavelength in the 1.3 μm band using the MOCVD method for the active layer. A refraction grating having a period of about 2000 Angstroms was provided near the active layer in view of the fact that this is a DFB structure.

In Figure 4 we plot the relationship resonance frequency and the vias level standardized for the threshold current, for the conventional bulk structure and the MQW structure adopted by us for the element. We can see that the incline is steeper, and a higher resonance frequency obtainable, with the MQW structure. With an MQW structured

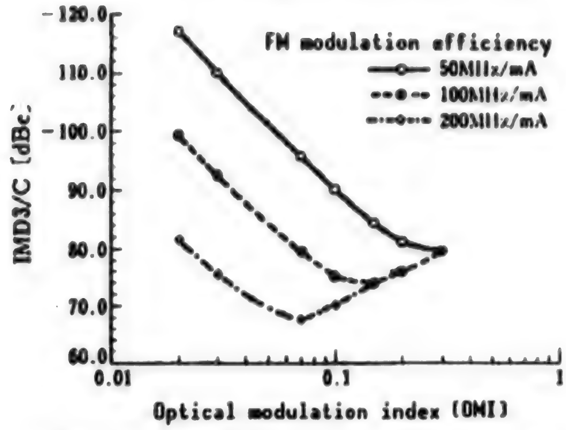

Fig. 2 (a) IMD3/C dependence on OMI (fixed Δν)

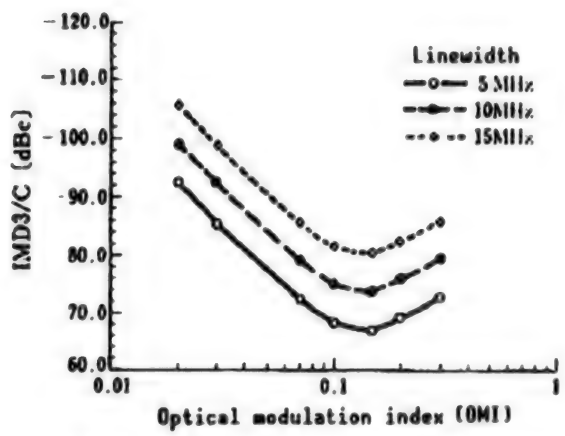

Fig. 2 (b) IMD3/C dependence on OMI (fixed β)

Figure 2.

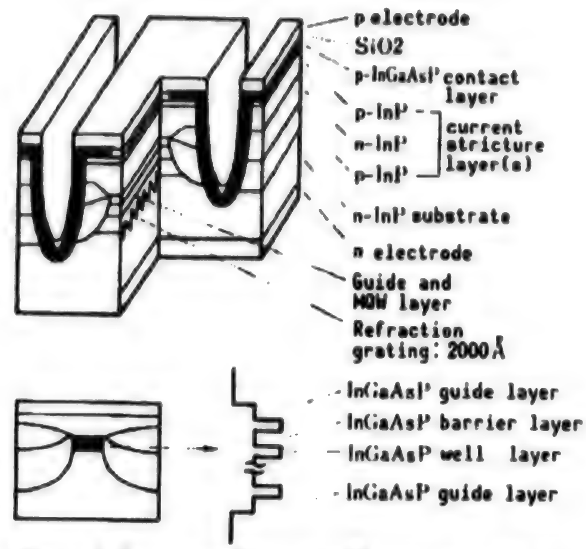

Figure 3. Schematic Diagram of Device Structure and Energy Levels

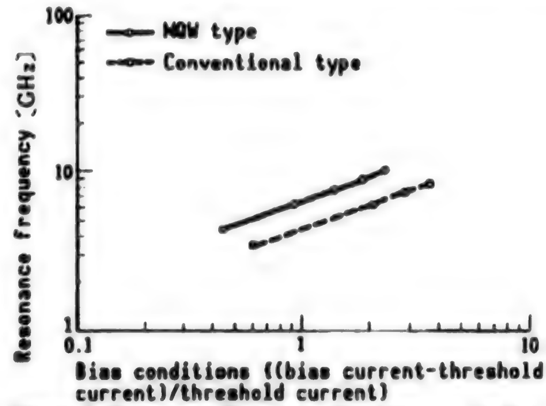

Figure 4. Resonance Frequency Dependence on Bias Conditions

element, we obtain a resonance frequency of about 8 GHz at an element optical output of 15 mW.

Next, in Figure 5, we plot the relationship between the thickness of the guide layer near the active layer, the FM modulation efficiency, and IMD3/C. By making the guide layer thinner (1000 Angstroms 100 Angstroms), the FM modulation efficiency is reduced greatly, from 700 to 100 MHz/mA. Along with this, the IMD3/C is also improved by about 20 dB,as we can see. In order to observe the correspondence with our simulations, we plotted the experimental values of the fluctuations in IMD3/C, computed values of IMD3/C based on a semiconductor laser element, and computed values for IMD3/C based on the optical transmission system, all while varying the bias level. These are all shown in Figure 6.

From Figure 6 we can see that the experimental values reflect the theoretical values of IMD3/C based on the semiconductor laser at low bias levels and the theoretical values of IMD3/C based on the optical transmission

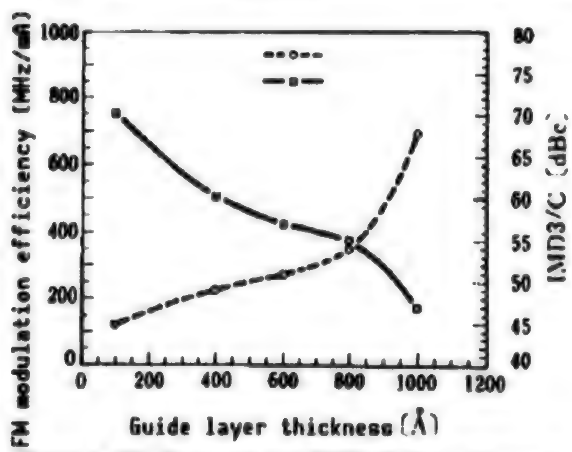

Figure 5. FM Response and IMD3/C Dependence on Guide Layer Thickness

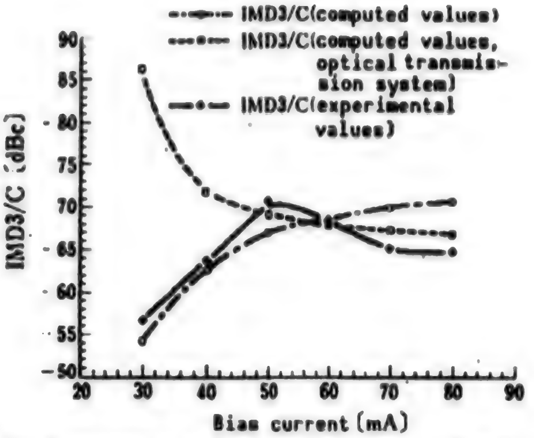

Figure 6. IMD3/C Dependence on Bias Current (Experimental and theoretical)

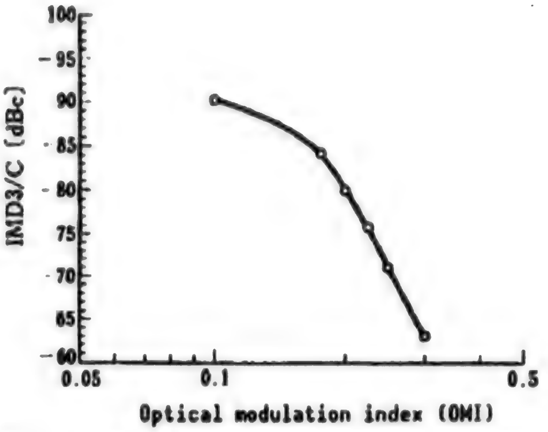

Figure 7. Relationship Between IMD3/C and Optical Modulation Index

system at high bias levels. The experimental and simulation values agree well, demonstrating the validity of the simulations.

We can now explain such IMD3/C behavior as follows. The resonance frequency of a semiconductor laser is low at low bias levels, in proportion to that bias level, but high at high bias levels.

On the other hand, the spectrum line width of a semiconductor laser is broader at lower bias levels, becoming narrower at higher bias levels. Accordingly, at low bias levels, the IMD3/C based on the semiconductor laser has a large impact, while at high bias levels the IMD3/C based on the optical transmission system has a large impact, indicating the characteristics noted above.

In addition to the conditions discussed in the foregoing, by optimizing such conditions as the composition and thickness of the MQW layer and the degree of detuning, we achieved favorable values for IMD3/C of $\leq$-80 dBc with an optical modulation index (OMI) of $\leq$0.2, as plotted in Figure 7.

4. Concluding Remarks

In a DFB laser for mobile communications applications, we made the guide layer thinner and adopted an optimized MQW structure, based on simulations, and were thus able to achieve an IMD3/C of $\leq$-80 dBc at an optical modulation index (OMI) of $\leq$0.2. We now plan to further improve the IMD3/C, and also move ahead with investigations on second intermodulation distortion which causes problems at higher frequencies and in the broadband systems used in cable TV networks.

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Mitsubishi Electric Corporation Develops High-Power Green Laser

94FE0404A Tokyo NIKKEI MECHANICAL in Japanese 27 Dec 93 p 38

[Article: "MELCO Central Research Develops Double-Output Green YAG Laser; Uses Multiple KTP Crystals To Halve Wavelength"]

[Text] Mitsubishi Electric Corporation's Central Research Institute has developed a YAG (yttrium aluminum garnet) laser with an output of 24 W which continuously generates a green light. This is roughly double the output of conventional green YAG lasers which have an output of about 13 W.

The fundamental wavelengths of YAG lasers are in the infrared region. In performing high-precision machining or processing, shorter wavelengths are advantageous, so potassium titanate phosphate (KTP) crystals are used to halve the wavelength so that green laser light can be used.

The wavelength conversion efficiency of a KTP crystal rises as the crystal becomes longer and the width of the

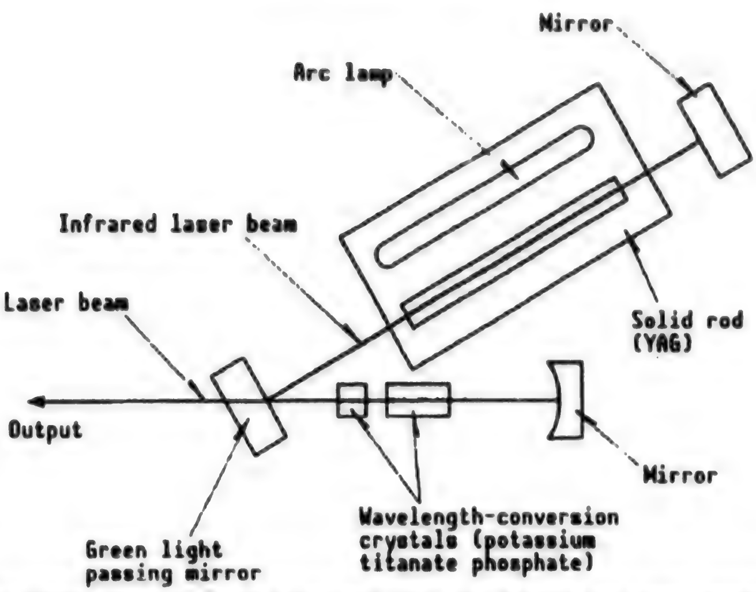


Figure 3. Optical System Model Diagram. Excited by an arc lamp, the infrared laser beam coming from the solid rod enters the wavelength-converting crystals, and is output as a green laser beam.

irradiating laser beam becomes narrower. However, the limiting length on crystals that can be stably procured is about 10mm. Also, when the width of the laser beam is narrowed and the output is raised, the beam damages the surface of the crystal. For this reason, 13 W is the limiting output for conventional green YAG lasers.

In the green YAG laser developed by MELCO's Central Research Institute, the width of the infrared laser beam striking the KTP crystals is set at approximately 10 times that of the conventional device, on the mm order, so that higher outputs can be achieved while preventing damage to the crystal surfaces. The decline in conversion efficiency resulting from widening the beam width is made up for by linking a number of KTP crystals together (Figure 3). The output beam is stopped down with a lens.

When the crystals are connected, and a phase differential develops in the green laser beams that are converted by each of the crystals, large outputs cannot be obtained because the laser beams create waves and cancel each other out. This being so, an interval is opened between the crystals such that the wavelengths of the green laser beams converted by the crystals line up. The phases of the converted green lasers follow the phases of the pre-conversion infrared laser beams. Accordingly, it is necessary that the phase of a converted green laser line up with the phase of the infrared laser remaining which was not converted by the previous crystal, when they strike the next crystal.

The surface of the KTP crystals is coated to prevent reflection. The coating layer thickness is controlled and the crystals are tightly connected to each other through the coating. The phases are matched by varying the refractive index and thickness of these coating layers. The materials used for these coating layers are oxide films which are mutually compatible. Their thickness is on the order of several tens of microns.

The Central Research Laboratory believes it now sees its way clear to implementing a 100W-class green YAG laser using this technology.

New Optical Coatings for High-Power Excimer Lasers

94FE0404B Tokyo NATIONAL TECHNICAL REPORT in Japanese Vol 39 No 4, Aug 93 pp 89-96

[Article by Takashi Iwabuchi, Katsuhiko Mutoh, and Takeo Miyata, Opto-Electro Mechanics Research Laboratory, Matsushita Research Institute Tokyo, Inc.]

[Text]

Abstract

This paper describes the multilayer coatings fabricated using a magnetron sputtering method and discusses the characteristics obtained.

In the Al_2O_3/SiO_2 multilayer mirrors fabricated on Si and SiC substrates, reflectivities of more than 99% have been obtained in the wavelength regions of both XeCl and KrF excimer lasers. For antireflective windows, a reflectivity of 1% has been obtained in the $SiO_2/Al_2O_3/SiO_2$ trilayer systems coated on both sides of a CaF_2 substrate in the above two wavelength regions.

In XeCl laser-beam irradiation tests, the fabricated multilayers show higher optical damage thresholds than typical

commercial mirrors. Furthermore, the multilayers show no reflection spectral change, even when they are heated to 800°C.

1. Introduction

It is expected that high-power high-repetition-rate excimer lasers will play important roles in industrial applications such as laser abrasion, chemical phase processes, and lithography, and developmental expectations are high.[1-3] For example, the Super-Advanced Processing System Technical Research Union (AMMTRA) is developing an XeCl excimer laser with an output of 2 kW and a repetition frequency of 5 kHz.[2,4] With the development and use of lasers such as this, both transparent substrates and multilayer dielectric films having high damage threshold values will become important optical elements.[5-8]

To date, many instances of research on light damage and multilayer dielectric film coatings used in optical elements used in excimer layers have been reported.[9-17] According to these, in almost all cases, the coatings are implemented by resistance heating or electron beam deposition, and the optical damage thresholds are usually defined in terms of the irradiation laser light quantity required until some change is observed in the sample through an optical microscope.[14-16] Rainer, et al., used a Nomarski interference microscope observed various types of multilayer film surfaces before and after a one-shot irradiation from a KrF laser, and reported that they obtained damage threshold values ranging from 6 to 8J/cm^2 with a 13-layer-pair MgO/LiF multilayer reflecting mirror.[14] Ito, et al., studied the relationship between the damage threshold and residual absorption in optical elements used for KrF lasers and reported that the damage threshold value decreased as the optical absorption increased.[16] Gu and Tang achieved damage threshold values around 8.5 J/cm^2 with a $(ZrO_2$-$Y_2O_3)/SiO_2$ multilayer reflective mirror for an XeCl laser with 99.5% reflectivity.[17] On the other hand, in high-power excimer lasers which have high repetition rates and low pulse energy (2 J or less, for example), optical element damage is believed to result not from insulation breakdown due to the one-shot high-power irradiation, but mainly from the heat generated because of the light absorption that accompanies prolonged irradiation. Ito, et al., and Gu and Tang suggest the influence of heat on the damage.[16,17] Accordingly, prolonged laser irradiation and heating tests will be important in evaluating damage thresholds.[18]

In this article, after discussing the results of evaluating a number of different thin-film coatings, we report on Al_2O_3/SiO_2 multilayer reflecting mirrors and antireflective windows used with KrF and XeCl lasers. In making the coatings, we used the magnetron sputtering method which is believed to permit the formation of more tightly bonding, fine thin films than with resistance heating or electron beam deposition. We also discuss the results of evaluating multilayer damage thresholds in XeCl laser irradiation and heating tests.

The content of this article, moreover, was printed in T. Iwabuchi, et al., *Jpn. J. Appl. Phys.*, Vol 31 No 4, 1992, p 1065.

2. Magnetron Sputter Coating Tests

2.1 Coating Apparatus and Technique

In Figure 1, a simplified structural view of the magnetron sputter coating apparatus is given. The main unit includes an optical film-thickness monitor and a Kaufman ion gun for cleaning the substrate surface. Three targets are located inside the coating chamber, and multilayer films made up of different substances can be coated by turning the substrate holder. A high frequency (RF) of 13.56 MHz is used to generate the sputtering ions. A static magnetic field is applied in a direction parallel to each of the target surfaces, and the sputtering ion density is increased.

The coatings are made by the process described below. The substrates are cleaned with an organic solvent and placed in the coating chamber. Then an oil dispersion pump is used to exhaust the air to a back pressure of 1-10^{-4}Pa. After this, an argon ion beam (acceleration voltage 700 V, Ar gas pressure 2.0-10^{-3}Pa) is used to perform substrate surface etching to remove contamination from the substrate surface. Then, using pure argon or a mixture of argon and oxygen is used as the sputtering gas, sputtering is performed. The mixture gas is used in cases where there is not enough oxygen in the oxide film coated on. The etching and coating processes are done continuously so that the samples are not exposed to air, and the temperature of the substrate is kept constant during both processes.

2.2 Thin Film Coating

Based on research on the optical and physical properties of the thin films fabricated by the electron beam deposition

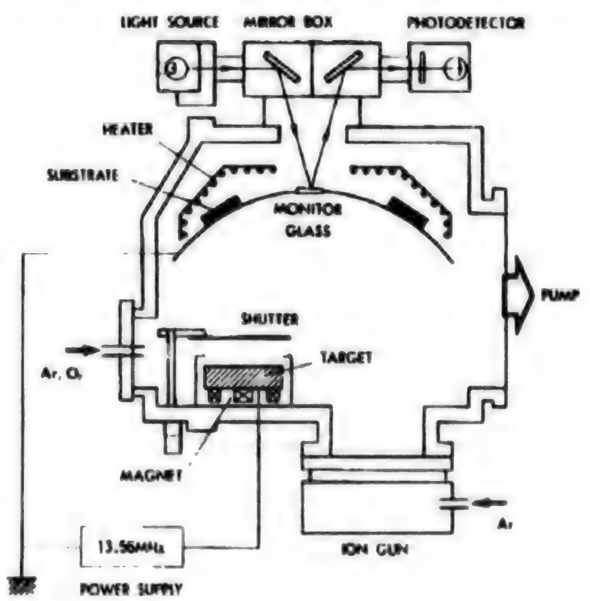


Figure 1. Schematic Diagram of the Magnetron Sputter Coating Apparatus

method, Rainer, et al., have reported on a number of kinds of promising oxides and fluorides for use in multilayer film optical elements used for excimer lasers.[14] With the magnetron sputtering method, it is generally easier to make oxide coatings than it is to make fluoride coatings due to the differences in the stability of the two elements and their controllability during coating. Meanwhile, in order to obtain multilayer film elements with high damage thresholds, low absorption is demanded, so transmissivity characteristics become important when selecting the substances configuring the multiple layers. Accordingly, we investigated the transmissivity spectra of a number of oxide films which had been coated on using the sputtering process. The thin films fabricated were SiO_2, Al_2O_3, MgO, Y_2O_3, HfO_2, and Sc_2O_3. Each of these thin films was coated on to the same optical thickness of 275 nm, with an RF power of 1.3 kW, onto synthetic quartz substrates of the same thickness. The sputtering gas pressure was 1.5-10^{-1}Pa and the substrate temperature was 100°C. In Figure 2 it is evident that, at a wavelength of 275 nm, the transmissivity of the Al_2O_3 film is close to that of the SiO_2 film, and higher than the other films. Accordingly, we selected Al_2O_3 and SiO_2 as the high-refractive-index and low-refractive-index substances for configuring the multilayer films.

3. Al_2O_3/SiO_2 Multilayer Element Reflection Characteristics

The reflectivity of Al_2O_3/SiO_2 multilayer films is influenced by stoichiometric changes caused by too little or too much oxygen in the configuring films. This is because it is stoichiometry which is one of the factors determinative of light refraction and absorption in the film(s). Meanwhile, the amount of oxygen in the oxide film(s), in coatings made by magnetron sputtering, is sensitive to the sputtering gas. In Figure 3, are plotted the reflectivity spectra for an Al_2O_3/SiO_2 multilayer (18-layer pairs) film for KrF lasers that is coated onto a synthetic quartz substrate using different sputtering gases. Other than that, the coating conditions are the same, with the sputtering gas pressure being 3-10^{-1}Pa and the substrate temperature being 150°C. In (a) case in Figure 3, where pure argon gas is used in the Al_2O_3 coat(s) and a mixture gas of argon (90%) and oxygen (10%) in the SiO_2 coats, the highest reflectivity is obtained. From this, with the coatings described below, we used these sputtering gas conditions for everything.

The reflectivity of the 18-layer-pair multilayer reflecting mirror coated on the synthetic quartz substrate, represented at (a) in Figure 3, is 98%, but we increased the reflectivity to 99% by increasing the layer pairs to 24. Also, by using silicon or SiC instead of synthetic quartz for the substrate, we further increased the reflectivity. In Figure 4 we have plotted the reflectivity spectra for Al_2O_3/SiO_2 multilayer reflective mirrors (24-layer pairs, Si substrate), at (a) for KrF lasers, and at (b) for XeCl lasers. We achieved better than 99% reflectivity in both cases, for KrF and for XeCl lasers.

In Figure 5 we have plotted the reflectivity spectra for the antireflective windows, for KrF lasers at (a) and for XeCl lasers at (b). The windows are structured by coating a trilayer film of $SiO_2/Al_2O_3/SiO_2$ onto both sides of a CaF_2 substrate. A reflectivity of 1% is obtained for both those for

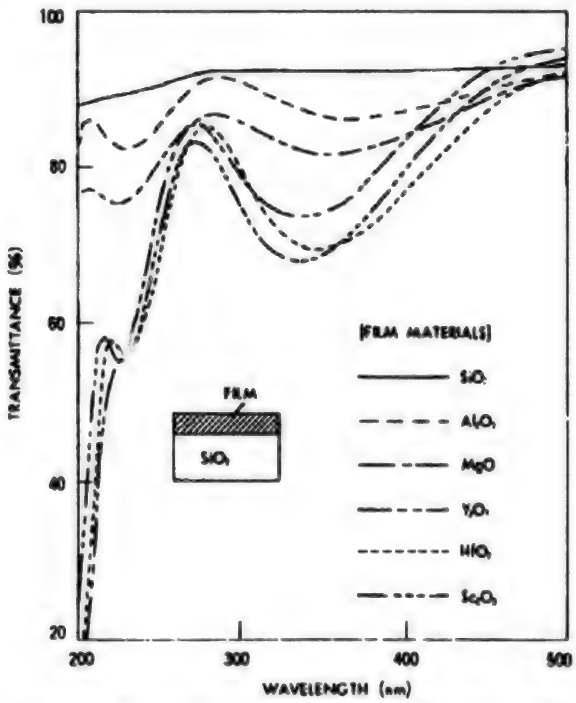


Figure 2. Transmittance Spectra of Oxide Films With an Equal Optical Thickness of 275 nm Coated on Substrates of Synthetic Fused Silica With a Constant Thickness

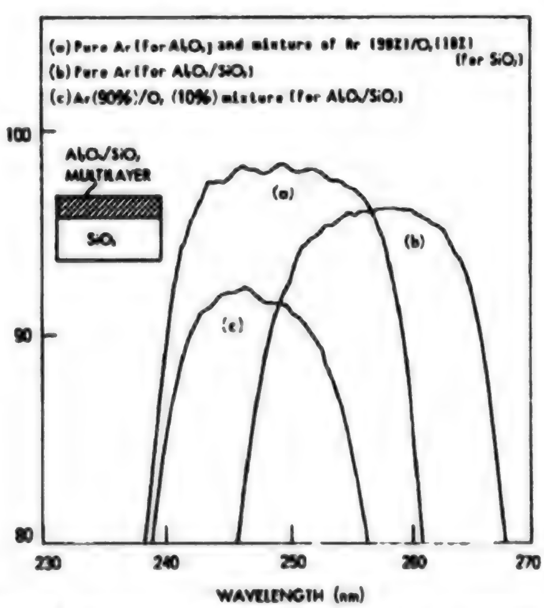


Figure 3. Reflectivity Spectra of Al_2O_3/SiO_2 Multilayer Mirrors With 18-Layer Pairs for KrF Lasers Coated on Synthetic Fused Silica Glasses Using Different Sputtering Gases

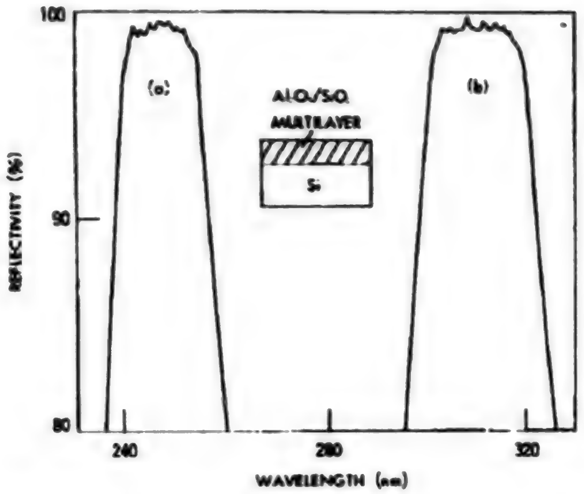


Figure 4. Reflectivity Spectra of Al_2O_3/SiO_2 Multilayer Mirrors With 24-Layer Pairs for (a) KrF and (b) XeCl Lasers Coated on Silicon Substrates

KrF lasers and those for XeCl lasers. This is estimated at about 99%, converted to tra^smissivity, from the lowness of the absorption coefficient inside the CaF_2 substrate, namely on the order of $10^{-4}cm^{-1}$. Generally, when light absorption inside a window—both sides of which have the same reflectivity—can be disregarded, the overall window reflectivity R is given by the following formula (1), where r is the reflectivity per side.

$R = r + r(1-r)^2 + r^3(1-r)^2 + r^5(1-r)^2 + r^7(1-r)^2 + yyy = 2r/(1+r)$ ....(1)

Therefore, the reflectivity r is given by the following formula (2).

$r = R/(2-R)$ ....(2)

Using Formula (2), the reflectivity of 1% obtained in Figure 5 can be converted to a reflectivity of 0.5% per side. If the conversion is made, we get 0.5% for the reflectivity obtained with one pair of $SiO_2/Al_2O_3/SiO_2$ trilayer films.

4. Damage Threshold Evaluation

4.1 Laser Irradiation Tests

We conducted XeCl laser irradiation tests on the Al_2O_3/SiO_2 multilayer reflective mirrors (24-layer pairs, SiC substrate) and on the antireflective windows ($SiO_2/Al_2O_3/SiO_2$ trilayer double-sided coating, CaF_2 substrate). The irradiation conditions and results are noted in Table 1. The laser beam was collected with a synthetic quartz lens and irradiated onto the test sample. The irradiation area was estimated from burn patterns onPolaroid film taken at the sample position and observed with an optical microscope, and found to be 0.1 cm^2. The irradiation pulse energy density was 1.5 J/cm^2 x pulse. This value reaches 0.15

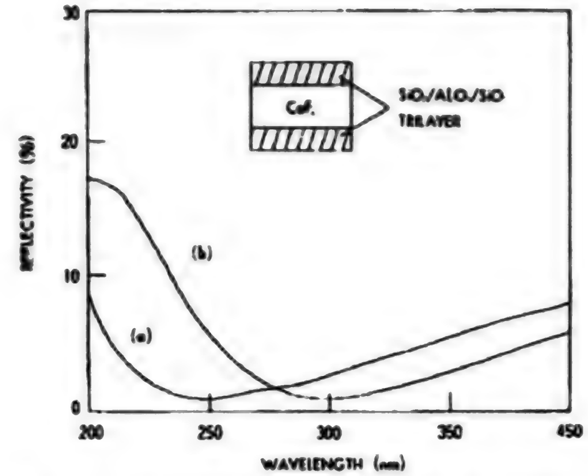


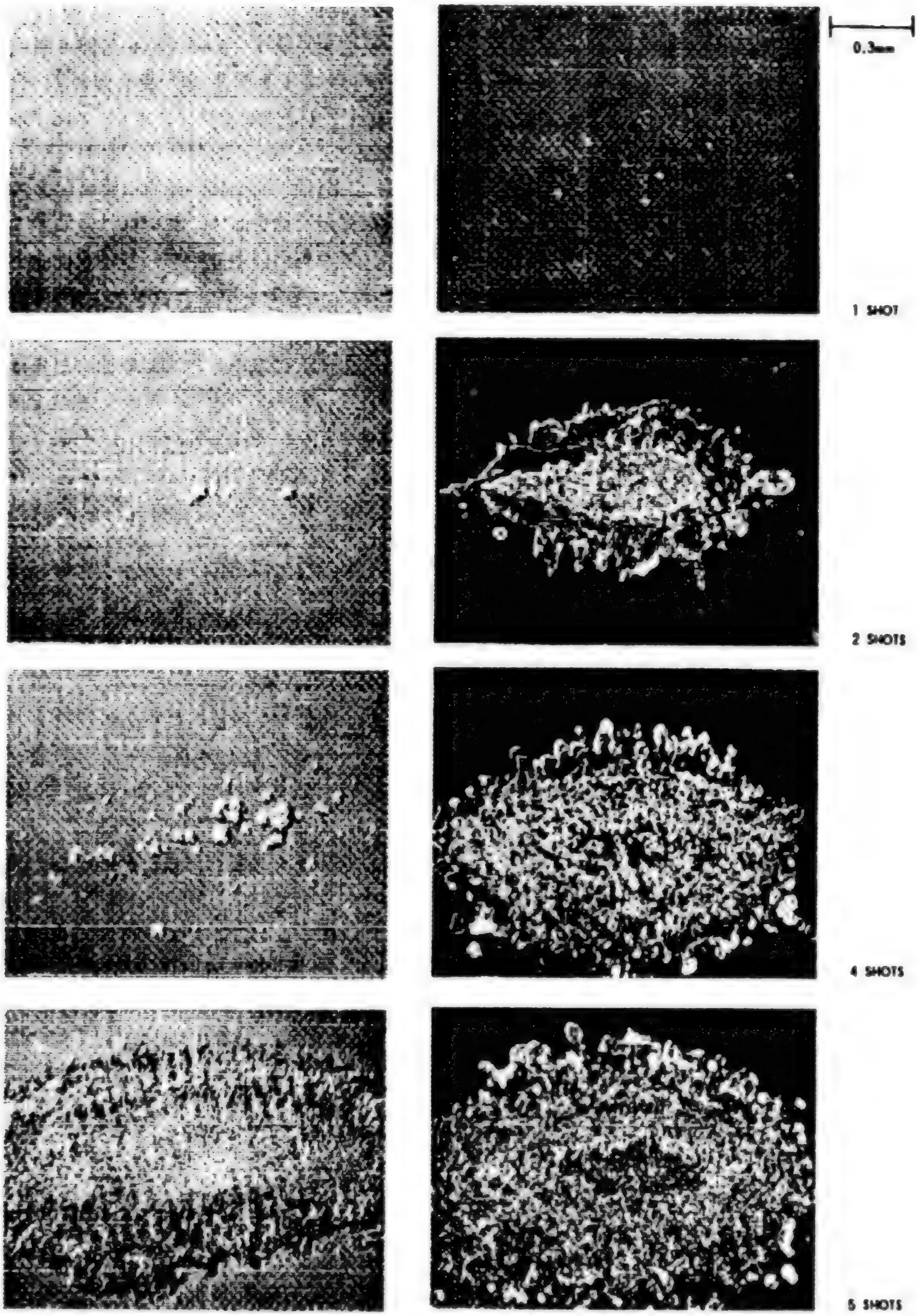
Figure 5. Reflectivity Spectra of Antireflective Multilayer Windows for (a) KrF and (b) XeCl Lasers

GW/cm^2 in terms of peak power density. Optical microscopic observations showed no change in sample surface morphology whatsoever after $1.8\text{-}10^5$ irradiation shots.

Table 1. Continuous XeCl Laser Irradiation Test Conditions, Results

Continuous laser irradiation conditions		Results
Average power	42 W	Surface morphology: No change
Repetition rate	300 Hz	
Pulse duration	10 ns	
Irradiated area to 0.1 cm^2		
Irradiated pulses	1.8×10^5	
Average power density	to 0.4 kW/cm^2	
Pulse energy density	to 1.5 J/cm^2 x pulse	
Peak power density	to 0.15 GW/cm^2 x pulse	

Also, using an XeCl laser having a pulse energy density of 9 J/cm^2 x pulse (peak power density 0.9 GW/cm^2 x pulse), multiple-shot irradiation tests were conducted on the samples in this research and on commercially available multilayer reflecting mirrors. The collecting laser beam irradiation technique was the same as in the tests described earlier. In Figure 6 are given optical microscopic photographs of the surfaces of multilayer reflecting mirrors after being irradiated with from one to five shots, using different samples. The samples at (a) and (b) in Figure 6 are, respectively, the Al_2O_3/SiO_2 multilayer reflecting mirror (24-layer pairs, Si substrate) of this research and a typical commercially available reflecting mirror (reflectivity 98.5%, synthetic quartz substrate). We can see that there are a number of minute pits in the surfaces of both samples after a one-shot irradiation.



(a) Al_2O_3/SiO_2 mirrors (24-layer pairs, Si substrate) of this study.

(b) Typical commercial mirrors (reflectivity: 98.5%, SiO_2 substrate).

Figure 6. Optical Microscopic Photographs of Multilayer Mirror Surfaces

In Figure 6(a), the size and number of the pits increases as the samples are irradiated with more shots. And dramatic film breakdown occurs in the samples after five shots. In Figure 6(b), however, this kind of film breakdown occurs immediately after but two shots. This difference is inferred to be due to differences in the atomic bonding energy in the multilayer films and in the bonding strength at the film-substrate interface, in the two samples. The pits that appear after one shot occur inside the sample or on its surface, and are thought to be caused by some kind of flaw or minute particles of impurities, for the reason that there is a tendency for light absorption or electric field concentration to develop at anomalous sites such as flaws or contaminant particles. Assuming this is correct, it should then be possible to further raise the threshold values by improving the coating process by, for example, eliminating the minute contaminant particles from inside the coating chamber.

4.2 Heating Tests

In order to elucidate the effects of heat, we evaluated the heat damage resulting from heat treatments on multilayer reflecting mirrors.[18] The samples used were Al_2O_3/SiO_2 multilayer reflecting mirrors (24-layer pairs) of this research and typical commerciallyavailable reflecting mirrors (reflectivity 98%, synthetic quartz substrate), both of which are elements used with KrF lasers. After performing heat treatment for 30 minutes at a constant heating temperature in an air atmosphere in an electric furnace, we made reflectivity spectrum measurements and conducted observations with an optical microscope to evaluate the condition of the samples after heating. Then we raised the temperatures on the same samples, and repeated the evaluation tests. We defined the heat damage threshold as the heating temperature at which an evident change first appeared in the reflectivity spectra of the samples.

In Figure 7 we have plotted the reflectivity spectra of multilayer reflecting mirrors before and after heat treatment. As shown at (a) in Figure 7, the spectrum of the Al_2O_3/SiO_2 reflecting mirror using the SiC substrate does not change even after heating to 800°C. When heated to 900°C, the entire spectrum shifts toward the shorter wavelength end, and yet no decline in the reflectivity is observed. We obtained the same results when heating the Al_2O_3/SiO_2 reflecting mirrors in which synthetic quartz substrates were used to 800°C. However, in this case, when heated further to 850°C, both a shift in the reflectivity spectrum toward the shorter wavelength side and a decline in the reflectivity (99→50%) were observed. The spectra of the commercial reflecting mirror, meanwhile, has already shifted toward the shorter wavelengths when heated to 300°C, as seen at (b) in Figure 7.

In Figure 8 we present optical microscopic photographs of multilayer film surfaces of the Al_2O_3/SiO_2 reflecting mirror (SiC substrate) after heating to 900°C (a), and of a commercially available reflecting mirror after heating to 350°C (b). At (a), we see that the surface morphology is smooth, and observe no changes before and after heat

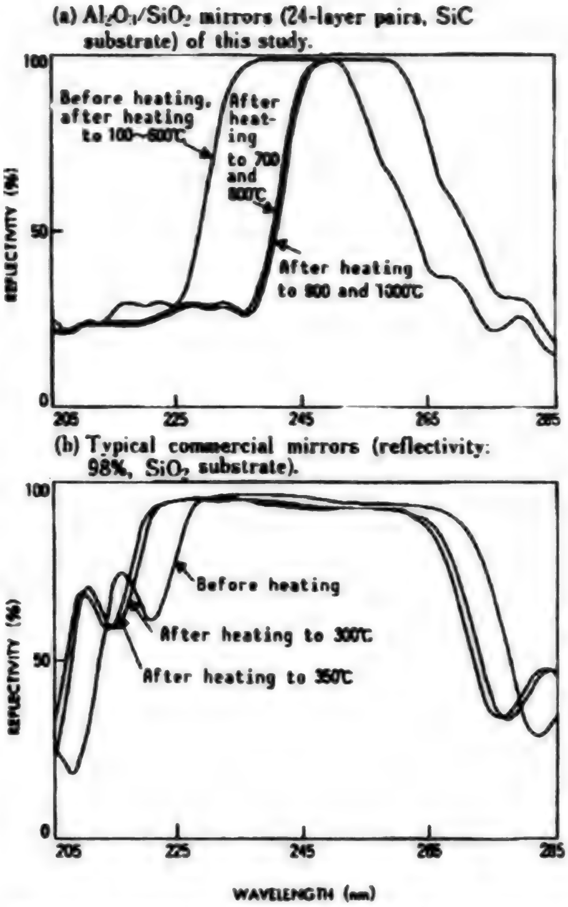
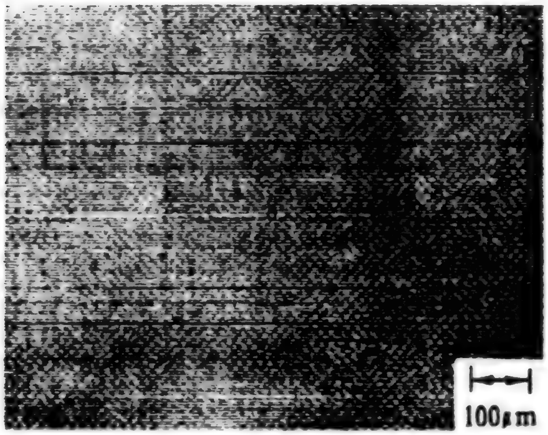


Figure 7. Reflectivity Spectra of Multilayer Mirrors for KrF Lasers Before and After Heating Tests

treatment. The same results are obtained with Al_2O_3/SiO_2 reflecting mirrors using silicon substrates. When synthetic quartz substrates were used, although no cracks developed after heating to 850°C, partial multilayer film peeling did occur. Meanwhile, with the commercial mirror shown at (b), many cracks have developed in the multilayer film. From the foregoing, we can conclude that the heat damage threshold is above 800°C for the reflecting mirrors of this study, but below 300°C for typical commercially available reflecting mirrors.

In Figure 9 we represent X-ray diffraction profiles, before and after heating, for the Al_2O_3/SiO_2 multilayer reflecting mirrors (Si substrate) of this study. The before-heating profile is shown at (a) and the after-heating profile at (b), where we only the Si (111) from the substrate and the (222) peak. At (c), however, which is the profile after heating to 900°C, we observe multiple peaks, noted by the letter "A" in the figure. These peaks have been identified as the diffraction lines from the Al_2O_3 crystal(s).[19] Accordingly,



(a) Al_2O_3/SiO_2 mirrors (24-layer pairs, SiC substrate) of this study after heating at 900°C.

(b) Typical commercial mirrors (reflectivity: 98%, SiO_2 substrate) after heating at 350°C.

Figure 8. Optical Microscopic Photographs of Mirror Surfaces

it is now evident that the spectrum shift in the Al_2O_3/SiO_2 reflecting mirror after heating to 900°C is due to a change in the optical thickness causedby the crystallization of the Al_2O_3 layer(s).

5. Conclusions

We used the magnetron sputtering method to fabricate multilayer reflecting mirrors and antireflective windows for use with KrF and XeCl lasers. In these we achieved a reflectivity of 99% in Al_2O_3/SiO_2 multilayer reflecting mirrors and of 1% (equivalent to 99% transmissivity) in antireflective windows employing $SiO_2/Al_2O_3/SiO_2$ tri-layer film. In continuous irradiation tests with the XeCl laser (pulse energy density 1.5 J/cm^2 x pulse), we found no changes in the surface morphology of either the reflecting mirror or the antireflective window after $1.8\text{-}10^5$ shots. In XeCl laser irradiation tests with the pulse energy density at 9 J/cm^2 x pulse (peak power density of 0.9 GW/cm^2 x pulse), we demonstrated that, as compared to typical commercially available reflecting mirrors, the reflecting mirrors of this research exhibited high optical damage threshold values. We also found that the heat damage threshold for the devices of this study were above 800°C, and that the spectrum shift after heating to 900°C is caused by the crystallization of the Al_2O_3 layer.

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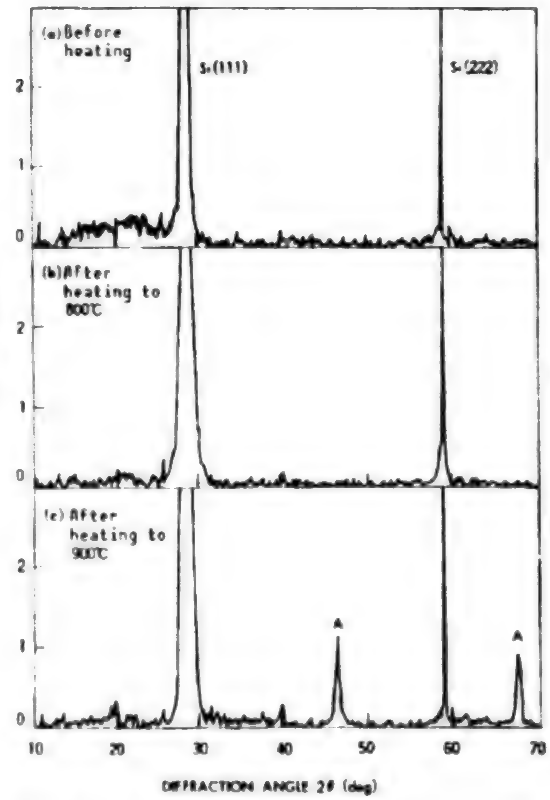

Figure 9. X-Ray (CuKα: λ = 0.15418 nm) Diffraction Profiles of the Al_2O_3/SiO_2 Mirror (24-layer pairs, Si substrate) Before and After Heating Tests

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New Type of High Speed Optical Scanner for Laser Market

94FE0420A Tokyo TOSHIBA REBYU in Japanese Vol 48 No 10, Oct 93 pp 787-790

[Article by Yoshimasa Yoshida]

[Text]

Abstract

This paper introduces a pen type YAG (yttrium-aluminum-garnet) laser marker, LAY-724D series, which has been developed for high-speed marking. The LAY-724D is equipped with a new type of optical scanner which has small and light scanner mirrors, enabling it to achieve high-speed marking of more than 120 characters per second.

The main model of the LAY-724D, model LAY-724DC, incorporates a laser of high luminous intensity in order to rapidly mark metal and ceramics.

1. Introduction

Laser marking is the process of irradiating the object to be marked with a laser beam to cause partial removal or transformation of the material, so that characters or shapes can be recognized due to the contrast between those parts and the surrounding material. With laser marking, clear, high-quality markings can be made at high speeds without contact. Also, since the process may readily be automated, it is being used widely in a broad range of applications, and is playing a large role in improving productivity and product quality.

Laser markers come in two main types, namely the master type and the pen type. The former is generally thought to be productivity-oriented, for high-volume production, while the latter is said to be oriented toward small-lot, multiple-model production. Nevertheless, in view of the marking objects and the scope of application preparations, the pen type is thought to constitute the dominant trend.

In this context, Toshiba is already marketing the LAY-724C pen type model. Now, however, we have developed the LAY-724D high-speed marker which sharply improves productivity over the LAY-724C. Here we introduce our main model in this series, the LAY-724DC.

2. Pen Type Markers

The principle of pen type marking is diagrammed in Figure 1. This type of laser marker uses a Q-switch-equipped CW-YAG laser as its light source. The

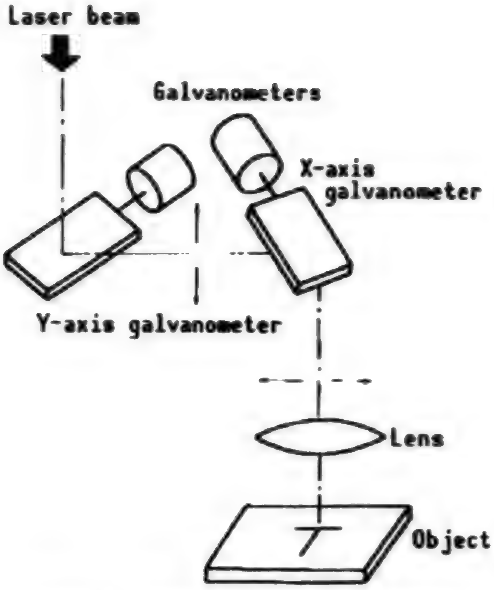

Figure 1. Principle of Pen Type Marking

laser beam is made to scan with a galvanometer type beam scanner which uses two perpendicular mirrors, and then focused on the work with a special lens that is called an Fθ lens.

The marking characters and graphics are handled by a computer as vector font data consisting of collections of straight lines and curves. The pen type marker combines these sequentially in marking the object. An example of such a marking is given in Figure 2.

3. Development Background

The pen type marker can be almost completely controlled by computer, including setting up and editing the marking. Thus it is a very general-purpose device which readily lends itself to on-line and FA (factory automation) environments. Also, its having a condensing optical system enables the power density at the marking point to be high, so that metals and ceramics can be marked as well as plastics.

Breaking down the demand for this pen type of marker—if we exclude the demand for on-line, special graphics marking, and other peripheral applications—diverges in two directions, namely toward high output and high speed.

The demand for high output is the demand for deep marking in metals and ceramics. This demand has already been met by the addition to our existing line a model featuring a high-powered, high-luminous-intensity, Q-switch-equipped YAG laser.

On the other hand, higher speeds are clearly demanded for higher productivity. In order to meet this demand, we speeded up the LAY-724D, achieving the highest processing speeds in the industry with this type of marker in a

Figure 2. Sample of Marking Using LAY-724DC

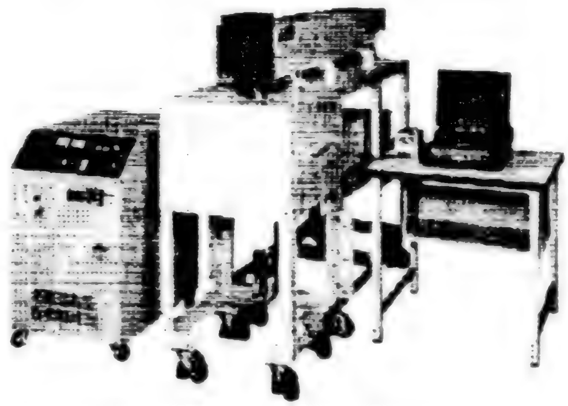

Figure 3. High-speed YAG Laser Marker, LAY-724DC

device that vies with the processing power of a mask marker. But in doing so we did not merely seek to improve the processing power for conventional marking applications. We also sought to expand the applications to fields which hitherto have demanded a mask marker, and even into applications which exceed the capabilities of mask markers, such as ceramic IC packages.

In our effort to achieve higher marking speeds, we focused on the beam scanner of the LAY-724D, and adopted a new type of high-performance galvanometer scanner. We also made the mirrors smaller and lighter in order to reduce the burden on the scanner.

The system is depicted in Figure 3, while its main specifications are listed in Table 1.

Table 1. LAY-724DC Specifications

Laser	
Model name	LAY-662D
Output	60W (at CW, oscillator units)
Spread angle	5 mrad or less
Beam scanner	

Table 1. LAY-724DC Specifications (Continued)

Type	Galvanometer scanner (X, Y axes)
Scanning speed	Max 4000mm/s (at 10μ resolution, linear)
Print speed	100 characters/second or more*
Scanning range	φ 100mm
Focal length	180 mm (work distance)
Marking Unit	Industrial computer
Execution control	J-3100 (standard specifications)
Man-machine interface	PMS2 (Pen type Marking System Ver. 2)*

Note: 1mm DIN font (uppercase alphabetic and numerals)

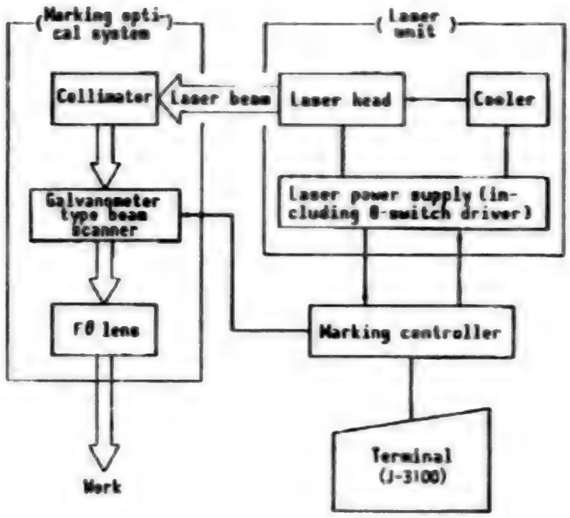

Figure 4. Configuration of LAY-724DC

4. System Configuration

The system configuration is diagrammed in Figure 4. As can been from this diagram, the system is made up of three main units, namely 1) a laser unit that serves as the light source, 2) a scanner optical system that performs the marking, and 3) a control unit that controls 1) and 2).

We next describe each of these units.

4.1 Laser Unit

The laser unit which serves as the light source for the system is a CW-YAG laser equipped with an AO (acousto optic)-Q switch. This unit is made up of a laser oscillator built into the marker, and a power supply unit that includes the power supply itself, a cooler, and a Q-switch driver. In the LAY-724DC here discussed, a newly developed high-luminous-intensity laser LAY-662D is employed in the laser unit, which is the heart of the system. This laser was especially developed for high-speed marking and deep cutting. Compared to conventional lasers of the same power, this one has its spread angle cut roughly in half. Thus the power density at the process point can be made high, and so supplement the power during high-speed marking. This makes it possible to perform high-speed marking on metals and other work requiring relatively high power.

4.2 Scanner Optical System

This unit is configured with a perpendicular double-axis galvanometer arrangement attached to the mirrors, an Fθ lens, and a collimator. The F lens is a type of condenser lens, and is so designed that, even when the beam moves away from the center of the lens in a scan, the focus is kept at the same plane as that near the center.

In the LAY-724DC, we use a particularly short focal point Fθ lens, make the scanner mirrors smaller and lighter by lowering the collimator magnification, and thus reduce the load on the scanner. For the scanner it self we adopted a new type of high-performance galvanometer, thus suppressing hysteresis, and improving the tracking of the control unit. By so doing, character deterioration is done away with, even when the scanning speed is set high. In addition, the delay time required for positioning is sharply reduced, and the print speed at any given scanning speed is improved.

4.3 Control Unit

The controller is made up of a marking controller which actually controls the laser and the scanner, and thus the execution of the marking, and a man-machine interface (MMI) which edits and controls the data required for marking, and sends these data to the controller.

We use an industrial computer (hereinafter called the pen type marking system (PMS) controller) as the marking controller, and make the J-3100 series standard for the MMI. The marking data are edited on the J-3100,then sent to the PMS controller via a communications program. The PMS controller controls the execution. During execution control, operational control passes to the PMS controller, during which time the J-3100 normally functions as the controller terminal.

The software which controls the marker includes three types, namely an execution program and associated library which runs on the PMS controller, a data editing program which runs on the J-3100, and a communications program which connects the J-3100 and controller. However, we made some sweeping changes in the LAY-724DC. In the data editing and execution areas, we improved the marking data precision and included more features such as bar code functions. We also modified the interface in the communications program to speed up data transfer and make it more user-friendly.

5. Performance Evaluation

With a pen type marker, the time required for marking is the sum of the actual marking time (called the actual

marking time), the delay time needed for positioning, and the time required for computer processing. Therefore the print speed is not proportional to the scanning speed which is set. This is due to the fact that, as the scanning speed is raised, the time required for positioning and computing becomes proportionately higher. This so-called lost time does not depend on the scanning speed, but on the nature of the marking and on the hardware. In order to raise the print speed, therefore, in addition to making the beam scanner capable of scanning faster, the lost time must somehow also be reduced.

This being so, we compared the LAY-724DC to the LAY-724CC in order to verify the degree to which the print speed is improved in the former. For this comparison we printed 2mm high DIN font numerals.

As a result, 400mm/s was about the highest scanning speed which could be set when marking the text with the LAY-724CC, whereas the LAY-724DC was capable of marking at 1000mm/s.

In Table 2 we note the actual print speeds for the scanning speeds set during the tests. As can be seen from the table, the print speed is definitely improved with the LAY-724DC at any given scanning speed. The degree of such print speed improvement is shown in Figure 5, where the marking speed is plotted on the horizontal axis.

Table 2. Relationship of Scanning Speed to Marking Speed

Marking speed (mm/s)	LAY-724CC $2mm^2$ (characters/sec)	LAY-724DC $2mm^2$ (characters/sec)	LAY-724DC $1mm^2$ (characters/sec)
10	1	1	3
20	3	3	7
30	5	5	11
50	8	9	18
70	11	12	24
100	14	17	33
150	20	25	45
200	23	31	52
300	29	42	71
400	33	52	83
500	37	60	95
700	—	66	108
1000	—	83	123

According to this graph, the faster the scanning speed becomes, the greater the degree of improvement, but this is due to the fact that the effect of compressing the delay time during marking is more pronounced at the high speeds where the effect of lost time is greater. Thus it is possible to enjoy the benefits of faster processing speeds even with work which prohibits the scanning speed from being set very high due to the constraints of the marking conditions.

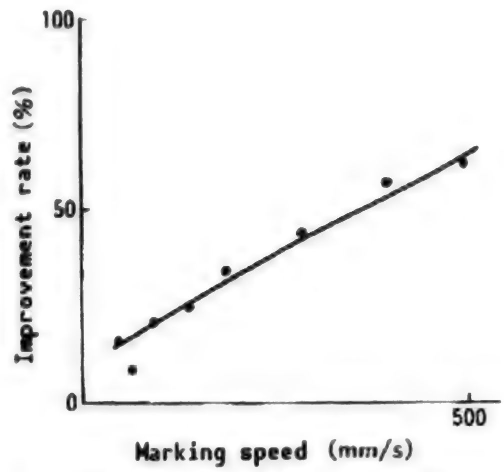

Figure 5. Improvement of marking speed

6. Concluding Comments

We have described the high-speed YAG laser marker LAY-724DC. This is a marker which was designed specifically to achieve faster marking speeds. It is capable of printing at 100 characters per second or faster. It achieves improved printing speeds even at ordinary marking speeds, as well as improved marking quality.

This series of marker has about the same line up as the previous LAY-724C series as far as laser selection is concerned. The system may be configured in many different ways to suit the application. As to its features, it reflects the data and know-how already accumulated with pen type markers, but has improved performance, and even greater general-purpose characteristics than before.

Characteristics of New Beam-Steering Lasers

94FE0421A Tokyo BULLETIN OF THE ELECTROTECHNICAL LAB in Japanese, Vol 57 No 9 Sep 93 pp 49-60

[Article by S. Mukai, M. Watanabe, and H. Ito: "Beam-Steering Semiconductor Lasers"]

[Text] Beam steering in semiconductor lasers is reviewed. Basic relations between the radiation (far-field) pattern and the optical electromagnetic field at the output facet are explained. Grating-coupler lasers, integrated deflector/laser devices, and twin-striped lasers are then introduced as typical examples of beam-steering lasers. Advantages and disadvantages of the characteristics of these lasers are discussed.

1. Preface

Beam steering is the most basic technique for controlling light and is widely used in various devices. In the past, rotating mirrors and ultrasonic steering elements were used for beam steering. If light can be steered by electronically controlling light-emitting elements and waveguides,

without using individual mirrors or steering elements, systems can be made smaller, faster, and more reliable, and the range of applications for beam-steering technology will expand further.

2. Relationship Between Direction of Outgoing Beam (Radiation Angle Distribution) and Optical Electromagnetic Field Distribution at the Output Facet

To steer an output beam without relying on moving mechanical parts, the phase distribution of the light at the output facet must be controlled. To determine the angular distribution of the light beam's intensity I(θ), we can think of the optical electric field at the output facet as a superposition of plane waves propagating in various directions, so then we can calculate the amplitude of those waves advancing in the θ direction. That is, the intensity of the waves advancing in the θ direction is determined by Equation (1) from the amplitude and phase distribution of the optical electric field (expressed as E(x), the complex amplitude).

$$I(\theta) = \left| \int E_x(x) \exp(ik_x(\theta)x)\ dx \right|^2 \qquad (1)$$

Here, $k_x(\theta) = k_0\sin\theta$ is the x component of the wave number vector of the plane wave advancing in the θ direction,

$E(x,z) = E_0(k_x, k_z) \exp(i(\omega t - k_x x - k_z z)))$ (2)

Where, (k_0 is the wave number of light in free space, $k_0 = 2\pi/\lambda$). However, we consider the electric field (E_x, 0, E_z) to have an x component and zcomponent only (Figure 1). When the electric field is perpendicular to the steering plane (the xz plane), i.e., parallel to the y axis, Equation (1') replaces Equation (1); when θ is small, there is not much difference between Equation's (1) and (1').

$$I(\theta) = \cos^2\theta \left| \int E_y(x) \exp(ik_x(\theta)x)\ dx \right|^2 \qquad (2)$$

When the light at the output facet is only distributed over a small region, even if the direction θ changes and $k_x(\theta)$ changes a little, we know from Equation (1) that the intensity I(θ) will not change very much. That is, the distribution of I(θ) dulls. (Because of diffraction, the irradiated beam broadens.) Thus, to obtain a sharp beam, the distribution of the light at the output facet must be broad. From Equation's (1) and (1'), the phase distribution inside the device may be controlled and the Fourier component of the electric field (corresponding to the spatial frequency $k_0\sin\theta_0$) may be made large in order to orient the beam in a specific direction ($\theta = \theta_0$). That is the basic mechanism of all of the beam-steering devices reported thus far. Next, we will explain about those devices.

3. Laser Integrated with a Diffraction-Grating Coupler

A spectroscope exploits the fact that the light diffracted by a diffraction grating is radiated at different angles according to the wavelength of the light. A beam-steering device can be realized by exploiting this property of diffraction gratings. For example, as shown in Figure 2, a waveguide provided with a 0.3-μm-pitch or 0.6-μm-pitch diffraction grating is integrated with a laser; when the wavelength of the laser light is varied, the direction of the beam radiating from the grating changes.

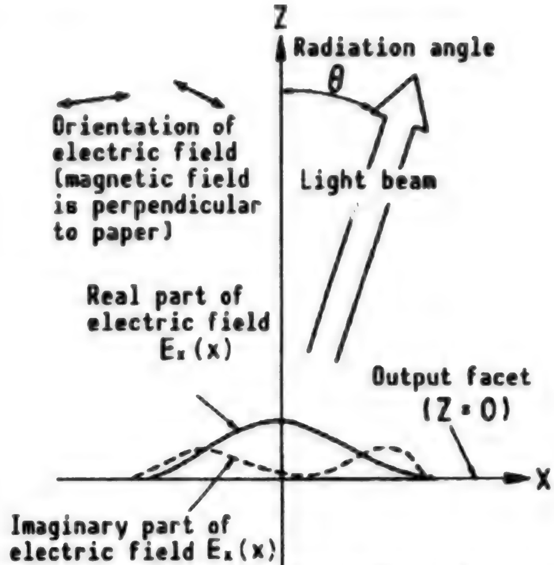

Figure 1. Distribution of Optical Electric Field at the Output Facet, and Radiation Angle Distribution

As for the optical electric field at the surface of the diffraction grating, the amplitude and phase of the light propagating through the waveguide $E_0\exp(i(\omega t - \beta x))$ are modulated periodically (with a period of Λ). If we express the modulation effect at the position x as a complex number M(x), we can write the following:

$M(x) = \Sigma_n M_n \exp(i(2n\pi/\Lambda)x)$ (3)

Then, the electric field at the output facet is given by Equation(4).

$E(x) = M(x)\,E_0 \exp(i(\omega t - \beta x)) = E_0 \exp(\omega t)\,\Sigma_n M_n \exp(i(2n\pi/\Lambda - \beta)x)$ (4)

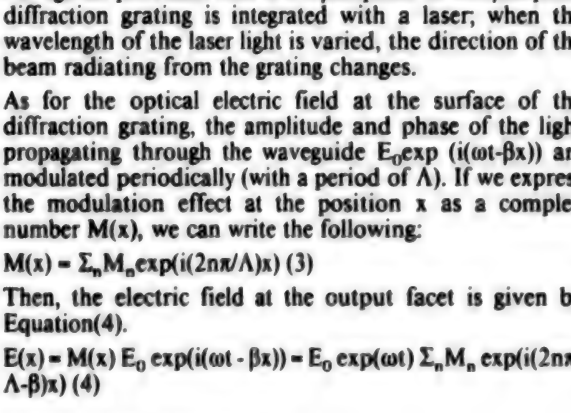

Figure 2. Beam-Steering Device that Integrates a Laser and Waveguide With Attached Diffraction Grating

From Equation (1) we know that at this time the direction of the outgoing beam θ is given by

$k_0\sin\theta + 2n\pi/\Lambda-\beta = 0$ (5)

where n is an integer. Because $\beta = 2\pi n_{eff}/\lambda$, where$n_{eff}$ is the effective refractive index of the waveguide and λ is the oscillation wavelength, when n_{eff} or λ change, we can vary θ in Equation (5) (i.e., steer the beam). Actually, by varying the wavelength in Equation (5), switching between three beams each separated by 2.5° and with a half width of 0.7° or less (a wavelength change from 846 to 862 nm)[1], and switching a 0.3°-wide beam in a direction 3° away at a 3° high speed (60 ps) (a wavelength change from 863 to 877 nm)[2] have been reported. The broadening of the light output from a laser integrated with a diffraction-grating coupler can be reduced to 0.06° by extending the length of the coupler to about 1 mm and suppressing waveguide loss.[3] On the other hand, because there is a possibility of being able to continuously vary the oscillation wavelength over a wide range of 85 nm,[3] there is the possibility that this method can be used to realize beam steering with hundreds of points of resolution.

In contrast to those methods that utilize wavelength variation, there is a way to steer light beams that involves a fixed wavelength and variations in the effective refractive index n_{eff}. However, that method has not yet been attempted because of the difficulty in getting large variations in n_{eff}. In the future, if quantum-well structures can be used to realize materials with a large range of variation in refractive index, a combination of a fixed-wavelength beam-steering method and such a material would be a promising candidate.

4. Laser Integrated with a Phase-Distribution Controller

Because the light source of the diffraction-grating coupler is the light propagating along the output facet, a light source whose spatial phase is stable over a wide range is easy to obtain. On the other hand, however, there are problems in that wavelength variations occur along with beam deflection; in reality, continuous beam scanning cannot be done; and the angle of beam deflection is relatively small. To make the angle of deflection large, there must be large variation in the phase of the optical electric field at two points near the output facet. The problem can be solved by using a phase-distribution controller[5]. Rather than making the output facet follow along the direction of the light's propagation, by placing the output facet normal to the direction of the light's propagation (the vertical direction), as shown in Figure 3, and by changing the transverse distribution $n_{eff}(x)$ of the refractive index of the waveguide that is just in front of the output facet, the phase-distribution controller gradually tilts the phase plane of the propagating light.

With that sort of device structure, there is only the refractive index distribution with no gain or loss in the waveguide. When the phase of the incoming light is spatially uniform, the phase of the electric field at the output facet, in a first approximation, becomes $-n_{eff}(x)L(2\pi/\lambda)$+const (L is the length of the phase-distribution controller). From Equation (1), the inclination of the outgoing light θ at that time is

$(2\pi/\lambda)\sin\theta - (dn_{eff}(x)/dx)L(2\pi/\lambda) = 0$

That is,

$\sin\theta = (dn_{eff}(x)/dx)L$ (6)

(The beam bends toward the side where the refractive index is large.) Because the left side of Equation (6) is proportional to L, we know that a large deflection angle can be obtained by making the length of thedevice L larger, even if the change in n_{eff} is small.

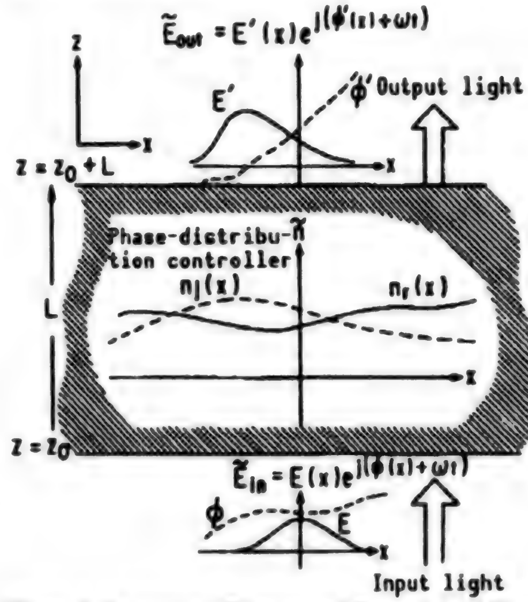

Figure 3. Conceptual Diagram of Operation of Phase-Distribution Controller

When the carrier concentration N_e in the active layer changes due to current injection, the refractive index of the GaAs layer n_{active} drops with respect to the 0.88-μm light as described in the following equation.[6]

$dn_{active}/dN_e = -1.2 \times 10^{-20}cm^3$ (7)

Consequently, if a pair of electrodes are set up on an AlGaAs double-hetero-structure waveguide that has a 0.1-μm-thick GaAs active layer, and current is injected asymmetrically, the waveguide's effective refractive index distribution becomes asymmetric, and the phase distribution of the guided waves can be tilted. Figure 4 shows the cross section of the device's structure and permittivities (the effective refractive index squared) calculated from that structure. From Figure 4 we see that it is difficult to get a uniform refractive index slope in the region where the light passes through the center of the device. Furthermore, because of the gain that arises in the active layer due to the current injection, as given in Equation (8),

$d(\mathrm{Im}(n_{GaAs})/dN_e = 2.4 \times 10^{-21}$ (8)

the distribution of the imaginary part of the refractive index also changes (the curved line ε_i), and the actual device is quite different from the idealized model based on Equation (6). After taking into account those effects as much as possible, we tried numerical calculations for the case of a semiconductor laser butt-joined to a 200-μm waveguide and irradiated with light to see what happens to the outgoing beam's angular distribution.[5] From the calculations (results shown in Figure 5), we know that the outgoing light is deflected. In comparison with the beam-steering characteristics of a diffraction-grating coupler, we know that continuous scanning is possible, and the steering angle of the scanning can be close to 20° On the other hand, directionality is poor: the angle of the beam's broadening may be as large as 5°. That is broadening due to diffraction because the light spot in the output facet is small.

Because the layered structure of this phase-distribution controller is the same as that of the laser, both can be integrated easily.[7] The fundamental problem is that the light entering the phase-distribution controller returns back to the laser again because of reflection. The purpose of the phase-distribution controller is to alter the shape of the wavefront of the propagating light, but when light whose wavefront shape has changed returns back to the laser, the laser's transverse mode is disturbed, and the light incident on thephase-distribution controller becomes unstable. Consequently, the beam-steering characteristics become unstable. One measure taken to solve this problem is to put a mode filter that suppresses all but fundamental-mode oscillation in the laser (to utilize the difference in mode gain in a 6-μm-wide, 2-mm-long mesa-type waveguide) so that, even if returning light is incident upon it again, the laser's transverse mode is not disturbed.[7] (Figure 6) Another measure is to coat the output facet with an anti-reflective film to keep reflected light from returning to the laser (in this case, the lengths of the laser and the phase-distribution controller are both 200 μm).[8] Figure 7 shows the beam-steering characteristics (experimental results) when the length of the controller is 200 μm and the device has the structure shown in Figure 6. A beam with 5°-wide broadening was continuously scanned across 13° to get what appears to be about three resolution points.

When we investigated beam-steering characteristics of devices made with different phase-distribution controller lengths, over the shorter device lengths the steering angles were confirmed to be proportional to the device lengths, as predicted (roughly) by Equation (6). However, for device lengths greater than 400 μm, the proportional relationship no longer holds. That is also surmised from accurate numerical mode analyses of waveguides composed of materials that have gain and loss. However, because a waveguide's gain is different for each mode, in a long waveguide only the large-gain modes remain, and the fact that the electric field distribution of the light, even light propagating beyond that, no longer changes becomes a problem.[5, 7] Consequently, to get a larger deflection angle larger by making the device longer, it is better to use a

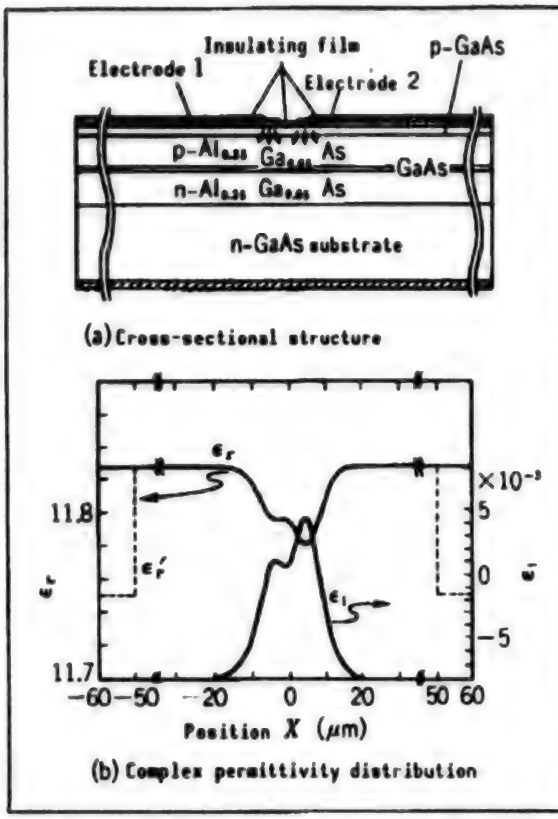

Figure 4. Cross-Sectional Structure of Phase-Distribution Controller, and Changes in Complex Permittivity Distribution due to Injected Carriers

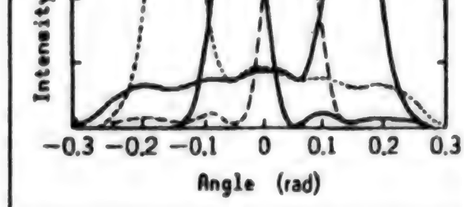

Figure 5. Outgoing Beam's Steering Characteristics Due to Phase-Distribution Controller, in Case Where Injection Current Is Varied

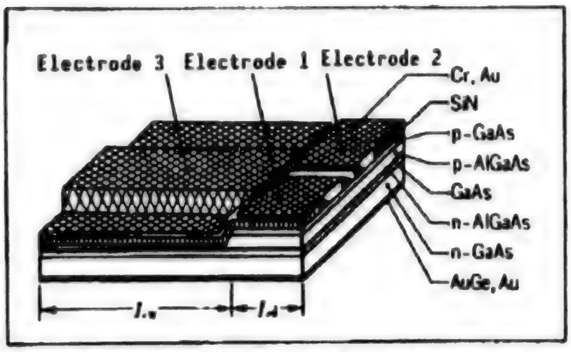

Figure 6. Laser and Phase-Distribution Controller Integrated Into a Beam-Steering Device in Which Mode Is Stabilized by a Long Mode Filter (L_W)

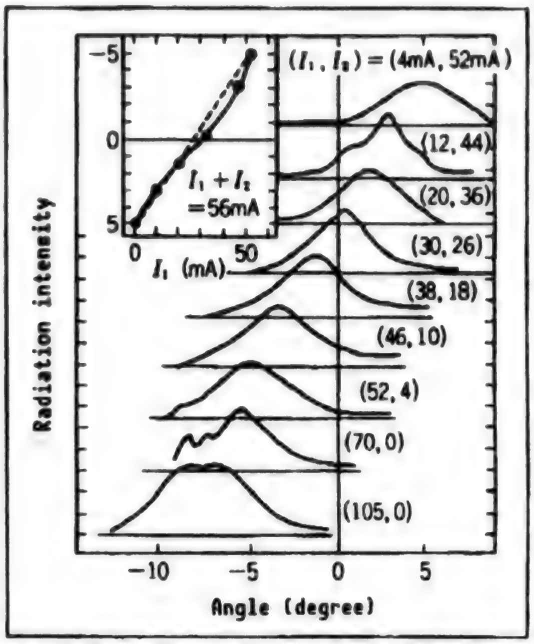

Figure 7. Beam-Steering Characteristics From Device That Integrates a Laser and Phase-Distribution Controller (Structure shown in Figure 6)

waveguide material whose gain differs very little between modes, i.e., a material whose refractive index is a real number. Actually, beam-steering experiments were carried out on an array of phase-control devices that was fabricated using a material with a large band gap and little light absorption.[9] As an extension of the simple beam-steering technology described above, shifting the interference fringes is considered. First, we fabricated an array of phase-control devices with a high degree of separation between devices to generate the interference fringes, then we integrated that with a semiconductor laser by means of butt-joining so that the light from the laser can be incident upon the array.[10] A 3° fringe interval pattern was obtained and adequate steering was realized, even though there was a 2π change in the phase of the interference fringes.

Using that sort of phase-distribution controller, we can not only tilt the wavefront, but we can also make the phase plane curve. In that case, the refractive index in the center of the controller may be made higherthan that of the area around the sides. The electrodes are positioned relatively distant from each other, as shown in Figure 8, so that there will be a higher carrier concentration in the area around the sides. When a wide beam is input so that the focusing effect is not cancelled by the broadening due to diffraction, the outgoing beam can be made to converge.[11] Figure 9 shows the data we obtained by regulating the injection current to electronically control the focal distance. With this sort of thin-film device, beam focusing only occurs in the direction parallel to the wafer; the beam cannot be focused in the direction perpendicular to the wafer. Recently, however, a lens with a two-dimensional cross section and electronically controlled focusing was developed using bulk $LiNbO_3$, a material in which the refractive index can be controlled by the electrooptical effect.[12]

Incidentally, results derived from research on phase-distribution controllers show that a carrier-injection

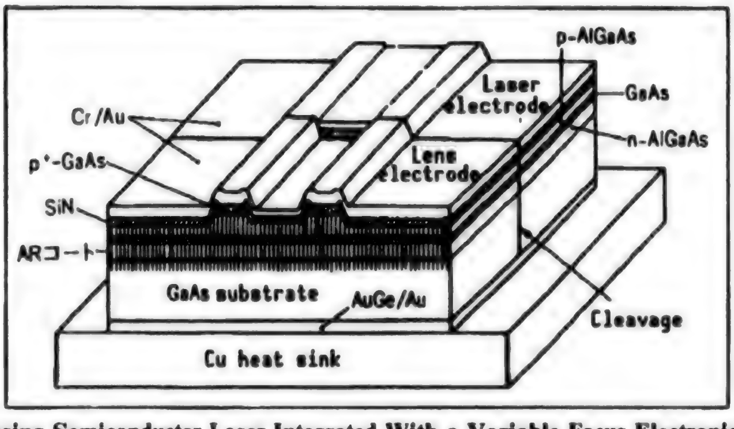

Figure 8. Beam-Focusing Semiconductor Laser Integrated With a Variable-Focus Electronically Controlled Lens

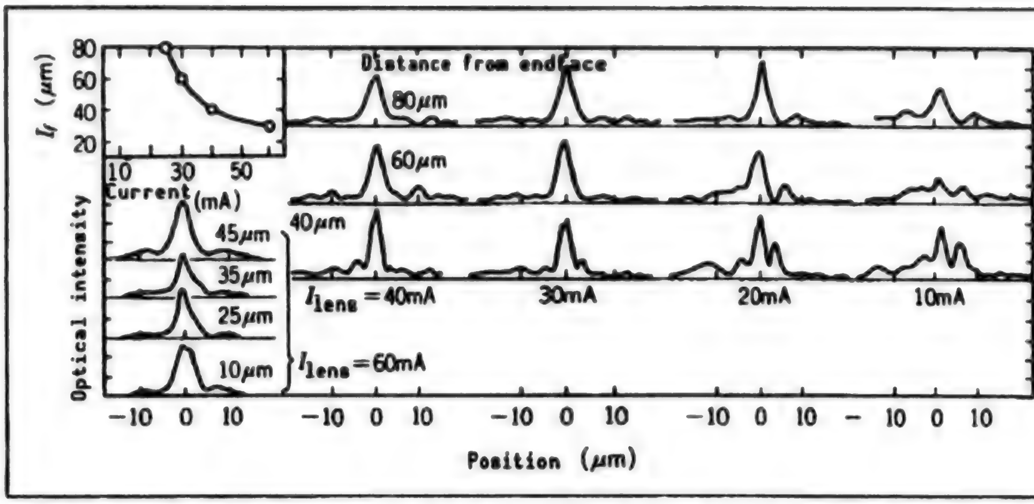

Figure 9. Focusing, Focal Distance Control of Beam Output From a Beam-Focusing Semiconductor Laser

phase-distribution controller integrated with a laser can also function as an optical amplifier during current injection. In the past, optical amplifiers with semiconductor laser structures were developed for the purpose of amplifying very weak light after the light passed through fiber in an optical communications system. By integrating the optical amplifier with a laser, the possibility of substituting that for a high-output laser is considered. We proposed an optical amp/laser integrated structure for high-output use. We were able to show theoretically as well as experimentally that the transverse mode is actually more stable during high-output operation, when the light is amplified to a high output in the optical amp that is integrated with the laser, than when a single-resonator laser operates at a high output. Figure 10 shows the structure of a high-output amp/laser integrated device. As the basic cross-sectional structure that decides the current bottleneck and the optical guided wave, the device adopts an internal stripe structure incorporating a current-blocking layer inside the semiconductor, which increases reliability during high output. Recently, the basic structure of this sort of amp-and-laser integrated device was used to realize an extremely collimated high-output beam.[3)] The characteristics during independent operation of the high-output semiconductor optical amplifier also improve. And, because a high optical output of 3.3 W was realized with a diffraction-limited 0.08°-wide beam, future developments are expected in high-output optical devices based on an integrated laser-optical amp structure.

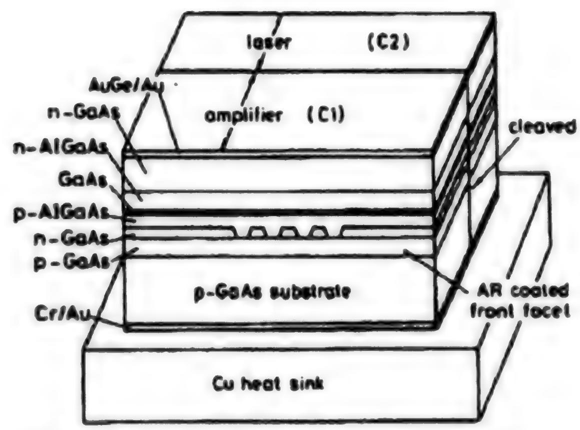

Figure 10. High-Output Amp/Laser Integrated Device

5. Beam Steering with Twin-Striped Lasers

In the beam-steering lasers discussed thus far, light is first generated in one section of the device, then the beam is steered by another section. If, instead, the device can generate light whose phase plane is already tilted from the start, the steering section would longer be needed, which would contribute toward smaller devices with simpler structures. Take for example the kind of twin-striped laser shown in Figure 11, which has a pair of electrodes placed close together on a mesa-type laser. If different currents are injected into Electrode 1 and Electrode 2 to make the carrier distribution in the active region asymmetric, using the relationships in Equations (7) and (8), therefractive index and gain distributions during oscillation inside the resonator can be set asymmetrically. In experimental observations, however, the outgoing light from that sort of laser veered to the low-excitation side.[15)]

The reason why the direction of the outgoing beam swings is that the equiphase plane of the light's electromagnetic field at the output facet slants, as given in Equation (1). If we numerically solve Maxwell's Equation to determine the intrinsic propagation mode in a waveguide that has asymmetric gain and refractive index distributions, an electric field distribution in which the equiphase plane is slanted

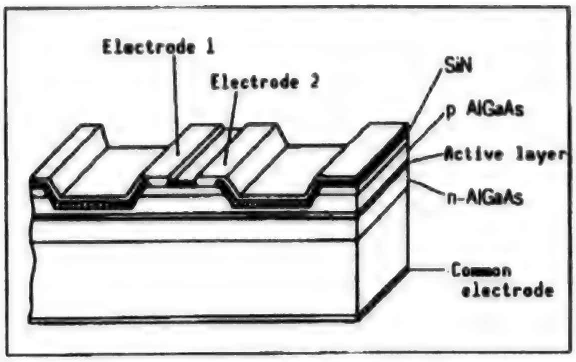

Figure 11. Twin-Striped Beam-Steering Laser

will be obtained. The following is an explanation of the physical mechanisms by which the wavefront of the oscillation light slants:

(1) Even with the oscillation-mode light propagating within the resonator, the distribution of the optical intensity is held constant.

(2) Because of that, regardless of the local position-dependent differences in gain, the light must be amplified by the same proportion on both the low-gain side and high-gain side.

(3) To amplify the light by the same proportion, the light energy generated on the high-gain side must flow to the low-gain side.

(4) In an isotropic medium like the active region of a normal semiconductor laser, the flow of energy is perpendicular to the phase plane. Therefore, in correspondence to that transverse energy flow, in the fundamental mode the wavefront slants, or, in a higher-order mode with flow components in the inherent relative transverse direction, the transverse components become unbalanced.

When we experimented with a laser oscillating in the fundamental transverse mode, the beam was scanned continuously, as shown in Figure 12. This indicates that the slant of the oscillation light's wavefront grows larger as the injected current becomes more asymmetric, which follows the idea discussed above. The range over which continuous scanning occurs is about 6°. If the deflection angle is increased by making the injection current more asymmetric, the laser shifts into higher-order mode oscillation, and discontinuous steering occurs when the oscillation mode changes. The oscillation mode shifts into a higher-order mode because of the following two points: (1) From Equation's (7) and (8), the refractive index becomes lower in places where the gain is high. (2) The fundamental mode tends toward the region where the refractive index is high, and the higher-order mode toward the region where the refractive index is low. For such reasons, as the electron distribution in the active region becomes asymmetric, the fundamental mode is pushed away into the low-gain region and the higher-order mode gain gets

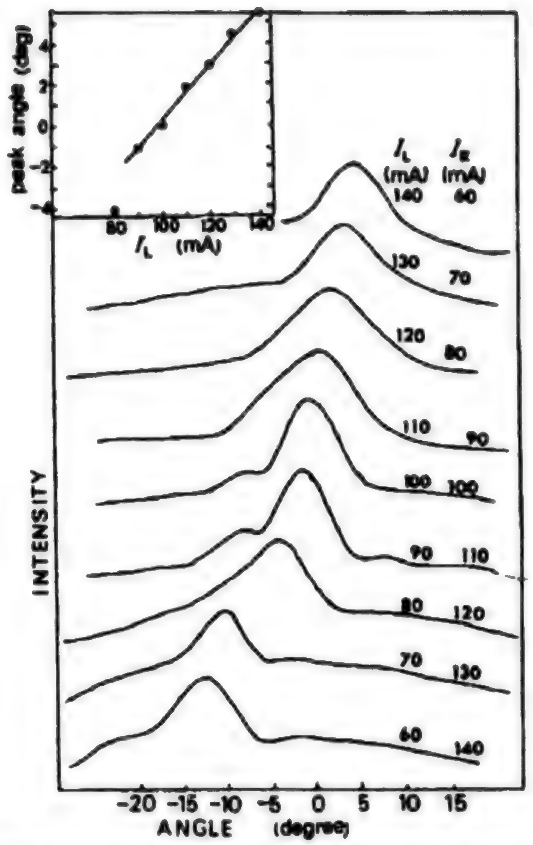

Figure 12. Twin-Striped Laser's Beam-Steering Characteristics During Fundamental-Mode Oscillation

higher, and, ultimately, the mode gain reverses itself.[16, 17] Consequently, to get a broader range of deflection angles in continuous scanning, a material whose differential change of refractive index (dn_{active}/dN_e in Equation (7)) is as large as possible must be used, or the laser's stripe structure must be highly selective toward the fundamental mode.

When we experimented with a laser oscillating in a higher-order mode, the directions of the peaks in the radiation intensity patterns were fixed, as shown in Figure 13, and only the ratio of radiation intensity between multiple peaks changes.[18] In that case, the angle between switched beams is determined by the width of the stripe; theangle is between 10° and 30°, and it is the angle between peaks when current is injected symmetrically. It was also confirmed that the switching speed is 1 ns or less.

Fundamental or higher-order oscillation mode can be selected by means of the stripe structure.[15] In general, in fundamental-mode oscillation, the light distribution concentrates around the center of the device; in higher-order-mode oscillation, a lot of light leaks into the low-gain, non-stimulated region outside of the stripe. Therefore, under normal operating conditions in which the center is stimulated strongly, the fundamental-mode gain

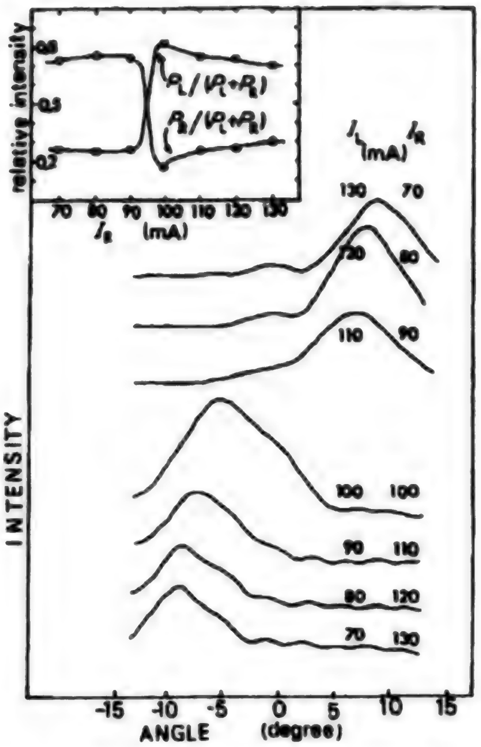

Figure 13. Twin-Striped Laser's Beam-Steering Characteristics During Higher-Order-Mode Oscillation

is high, and the higher-order-mode gain is low. If we make the mesa stripe narrower, the higher-order mode's protrusion into the non-stripe region becomes extremely large, the higher-order-mode gain drops, then that oscillation becomes impossible, and there is only laser oscillation in fundamental mode. Conversely, if current injection into the center of the device is inhibited and the gain there becomes lower than in the peripheral areas, the higher-order-mode gain grows higher, and there is higher-order-mode oscillation that does not depend on the gradient of the current distribution. The oscillation mode may be selected according to whether continuous scanning or signal distribution in a fixed direction is needed.

Either way, a large number of beam-steering resolution points is best, and for that it is better for the beam broadening to have a smaller angle. Beam broadening is mainly due to diffraction, which can be minimized by making the stripes wider to broaden the distribution of the light in the output facet. However, the stripes should not be too wide because the oscillation mode will become unstable. That is the weak point of this method, which is meant for generating light that has steering characteristics from the start inside the resonator. On the other hand, with this method the steering characteristics are not related to the length of the resonator, so even if short-resonator lasers become the mainstream in the future, this method can be applied. Because the deflection angle is comparatively large and applications in micro lasers are possible, there is the possibility that this method will be used in integrated optical circuits.

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CMP After-Processing and Washing Equipment

94FE0453A Tokyo SEMICONDUCTOR WORLD in Japanese, Mar 94 pp 82-94

[Article by Tokuro Eitoku, Dainippon Screen Manufacturing Co., Ltd.]

[Text]

1. Introduction

In the flattening processes that accompany higher-scale LSI integration, chemical-mechanical polishing (CMP) technology has been attracting attention in recent years. Uses of CMP technology in LSI fabrication processes, such as flattening interlayer insulating films[1] and multilayer metal embedding,[2] have been investigated by others, and a wide range of applications is anticipated.

On the other hand, an important point in the application of CMP in LSI fabrication processes is its success or failure in after-processing and washing. Because slurries of colloidal silica or other such material dispersed in an aqueous solution of an alkali base such as KOH are primarily used in CMP,[3, 4] a large amount of slurry particles and alkali metal ions are left on the wafer. After-processing and washing must completely remove those particles and metallic contaminants that are most detested in LSI fabrication processes.

Although CMP can be used to polish a variety of materials—oxide films (SiO_2), poly-Si,[5] and metals—the washing method also changes according to the type of film that covers the wafer surface. This article focuses on CMP for interlayer insulating films (oxide films, SiO_2).

State of the Wafer After CMP, What is Washed

1. Particles

Figure 1 shows a particle map on a wafer after CMP processing. After CMP processing, tens of thousands of particles (0.16µm/wafer) are usually seen. In addition to slurry, which is an abrasive material, the rough side of the abrasive pad is thought to account for most of the particles. To a certain extent those particles can be removed by washing the wafer with water, but to get the number of particles down to the strict levels required in LSI fabrication processes, another washing is necessary. Removing those particles is the biggest issue of post-CMP washing, and a high capacity for removing particles is needed. In addition, if the wafer is allowed to get dry just once after CMP processing, the particles that stick to the wafer are hard to remove. Therefore, care must be taken so that the wafer does not dry until the end of the washing process.

2. Metallic Contaminants

Because an alkali-based abrasive material is used in CMP, as mentioned above, the wafer surface inevitably becomes contaminated with an alkali metal (potassium). Figure 2 shows the results of total-reflection X-ray fluorescence analysis of the metallic elements on the surface of an oxide film (SiO_2) after CMP processing. In addition to potassium, metals such as calcium, iron, and zinc were detected. The washing process must remove particles as well as these alkali-metal and heavy-metal contaminants that are detested in LSI fabrication processes.

Post-CMP Washing Equipment

The following are required of post-CMP washing equipment:

(1) To process wafers onto which a large amount of particles adhere, the equipment should have high particle-removal capabilities.

(2) To process wafers contaminated with alkali and other metals, the equipment should be able to completely remove metallic contaminants.

(3) To prevent cross contamination and to isolate the wafer from other processes, the equipment should be used as a dedicated device. Layout with the CMP processing equipment should be simple.

(4) Because particle removal becomes difficult if the wafer is allowed to dry once, care must be taken so that the wafer does not dry until the washing is finished.

Table 1 shows the features of washing methods in cases where wafers are washed after CMP processing with various types of washing equipment.

Table 1. Post-CMP Washing Methods

Washing equipment	Washing methods	Advantages	Disadvantages
Batch washing device	• Ultrasonic washing • NH_4OH/H_2O_2 • DHF • Combinations such as H_2SO_4/H_2O_2	• High through-put	• Concern about cross-contamination • Large amount of water used • Large footprint • Chemicals are limited
Leaf-method spin washing device	• Ultrasonic washing • NH_4OH/H_2O_2 • DHF • Combinations such as H_2SO_4/H_2O_2	• Small footprint • Easy to keep the liquid pure	• Multiple chemicals are needed • Chemicals are limited

Table 1. Post-CMP Washing Methods (Continued)

Washing equipment	Washing methods	Advantages	Disadvantages
Leaf-method scrub washing device + batch washing device	• Scrubbing or ultrasound + • NH_4OH/H_2O_2 • DHF • Combinations such as H_2SO_4/H_2O_2	• Both particles and metallic contaminants can be removed	• Large footprint • Different through-puts • Brushes need to be replaced periodically
Leaf-method scrubber and chemical washing device	• Scrubbing + DHF • Scrubbing + NH_4OH/H_2O_2	• Small footprint • The liquid is clean • Small amount of chemicals used • Mainly particles and metal contaminants can be removed	• Brushes need to be replaced periodically

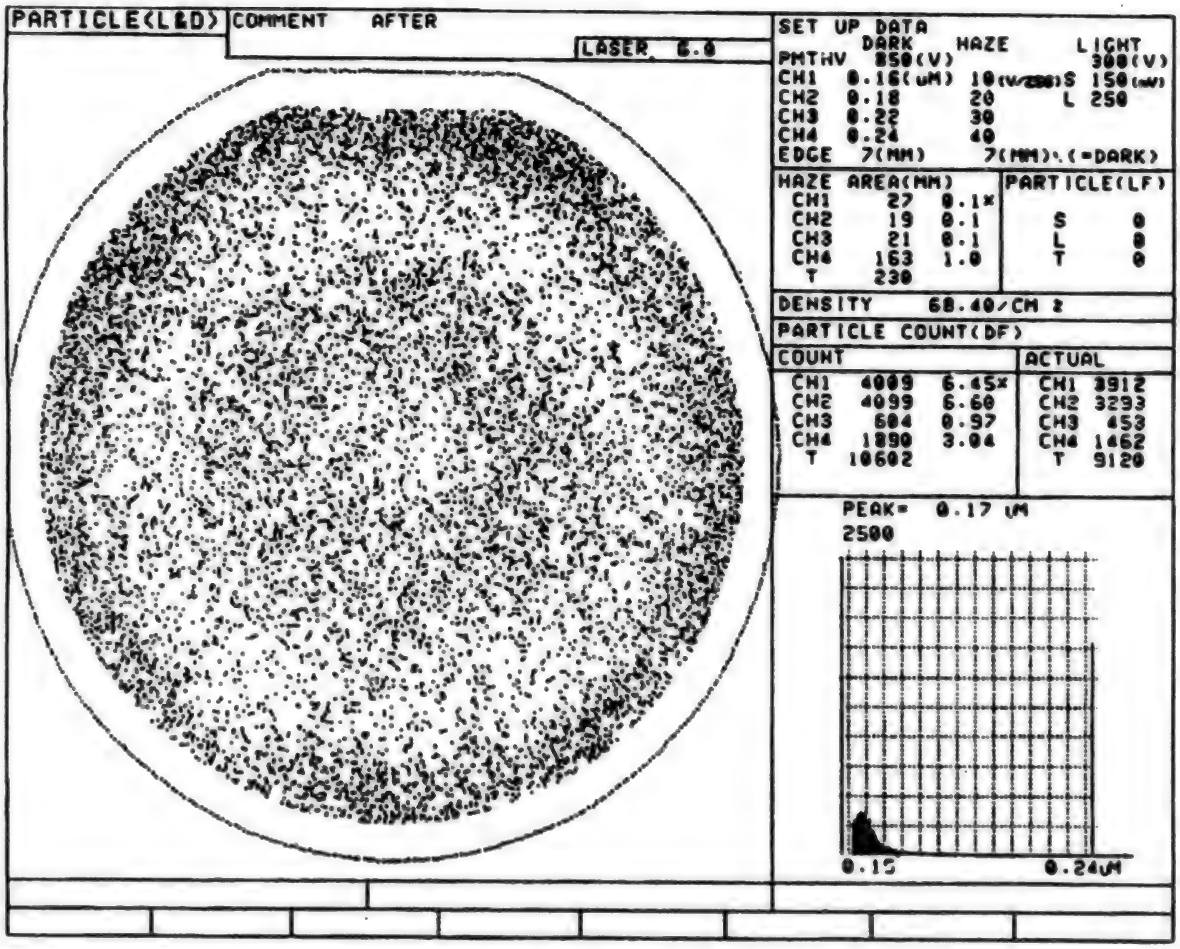


Figure 1. Particle Map After CMP Processing

In the case of the multi-vat submersible-type batch washing device, which has been widely used in the washing processes in LSI fabrication, many wafer can be washed at one time, and the through-put is high. On the other hand, to remove both particles and metallic contaminants, several chemical vats and waterwashing vats must be linked together; the batch washing device occupies a large area, which is likely to constrain the layout with CMP processing. Also, because wafers with a high degree of contamination will have to be processed, there will be concerns about cross-contamination due to the accumulation of

Spectrum	Energy (keV)	Integrated intensity (cps)	Content ($x10^{10}$)	B.G. (cps)
K-Ka	3.31	0.4854	99.29	0.0894
Ca-Ka	3.69	3.6985	545.65	0.1014
Ti-Ka	4.51	0.1329	10.76	0.1172
Fe-Ka	6.40	0.2466	7.19	0.1300
Ni-Ka	7.47	0.2309	4.49	0.2159
Cu-Ka	8.04	0.1797	2.89	0.3185
Zn-Ka	8.63	7.5230	99.91	0.4321

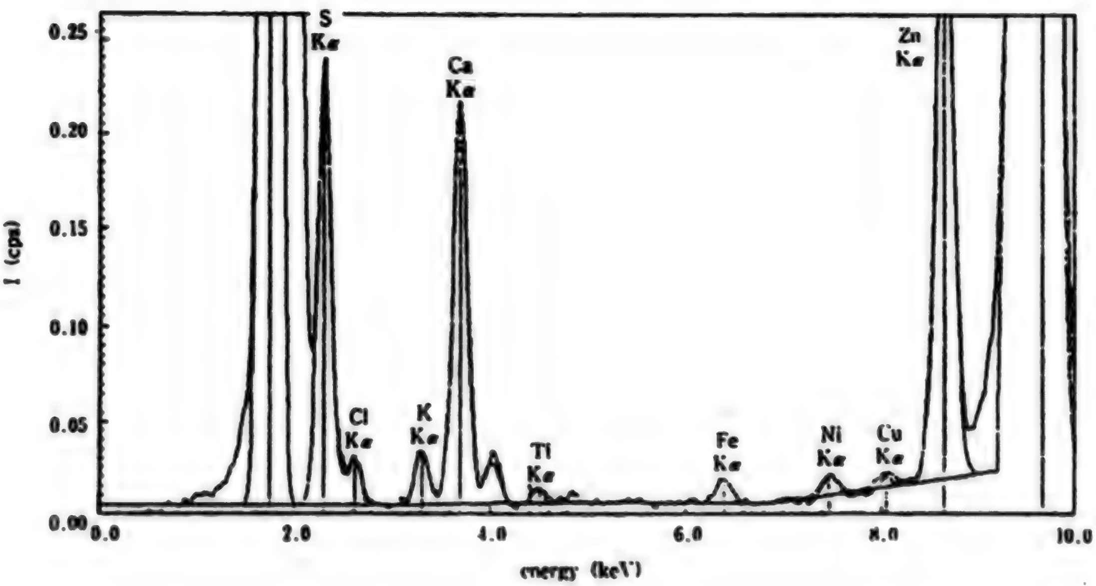


Figure 2. Results of Analyzing Wafer Surface Metals After CMP Processing

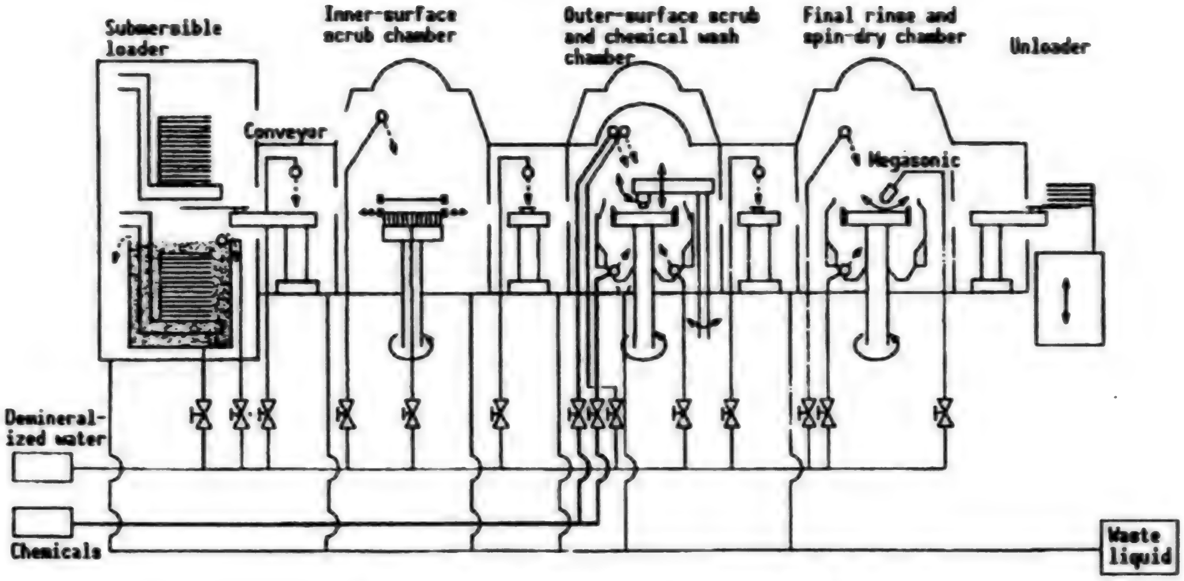


Figure 3. Configuration of the SPW-813-AS

contaminants in the washing chemicals. The chemicals need to be replaced frequently, too.

The scrub washing device, which uses brushes and sponges for removing particles, cannot remove metallic contaminants. It has also been considered for joint use with a batch washing device, but the cost of that is high because multiple washing devices are used.

The post-CMP washing device proposed by Dainippon Screen is a leaf-type scrubber and chemical washing device that has both scrubbing functions and chemical washing functions. This device occupies a minimal area, and both particles and metallic contaminants can be removed by a single washing device. The device's footprint can be kept small because brush scrubbing and chemical spray washing are done in the same chamber. Consequently, layout with a CMP processing device is easy.

The Scrubbing and Chemical Washing Device

Figure 3 shows the configuration of the SP-W813-AS, a scrubbing and chemical washing device developed by Dainippon Screen. The device is composed of three chambers: an inner-surface scrub chamber, an outer-surface scrub and chemical wash chamber, and a final rinse and spin-dry chamber. Because self-revolving brushes are used for scrubbing the outer surfaces of wafers, particle removal performance is high, and brush maintenance and replacement are easy. Wafers are held ready by the submersible loader until the washing starts to keep them from drying out. A chemical nozzle is set up inside the outer-surface scrub chamber, which enables chemical washing of the wafer's outer surface. This device's performance with respect to particles and metallic contaminants is described below.

1. Particles

Because this device washes wafers by means of physical action due to scrubbing and chemical action due to chemical processing, its capacity for removing particles is very high. Megasonic-spray washing is also possible. Figure 4 shows the device's ability to remove particles when wafers coated with an oxide film (SiO_2) and strongly contaminated with an abrasive material (slurry) were continuously scrubbed. Even after processing 5,000 wafers, the device could remove particles stably, down to the level before contamination or below that.

Figure 5 shows the results of removing particles from a wafer coated with an oxide film (SiO_2) that had actually been polished. More than 4,000 particles were counted after the wafer was rinsed with demineralized water only ((a) in Figure 5), but 95.4% of the remaining particles ($\geqq 0.2$ µm) were removed when the wafer was scrubbed ((b) in Figure 5). Then after a combination of scrubbing, washing with dilute hydrofluoric acid (DHF 0.5%), and megasonic rinsing, 98.8% of the particles remaining after the initial water rinsing were removed ((d) in Figure 5).

2. Metallic Contaminants

After chemical-mechanical polishing, wafers are contaminated with alkali metals such as potassium and heavy metals such as iron and zinc. Chemical washing is essential because those metallic contaminants cannot be removed by water rinsing and water scrubbing.

Figure 6 shows the results of total-reflection X-ray fluorescence (TXRF) analysis of the metallic impurities on the surface of an oxide film (SiO_2) that had undergone scrubbing and chemical washing in the SP-W813-AS. After

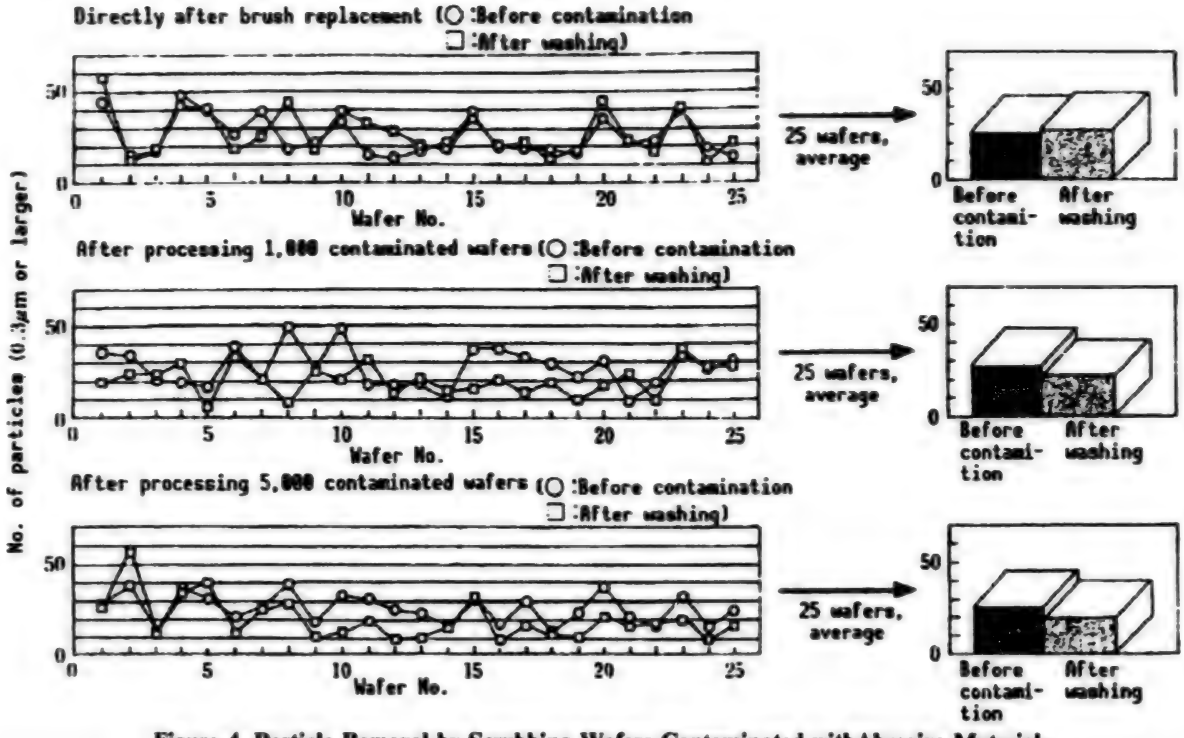


Figure 4. Particle Removal by Scrubbing Wafers Contaminated withAbrasive Materials

being polished during the CMP process, the oxide film underwent only water scrubbing; potassium, iron, and zinc contaminants from the polishing remained on the film. When the film was alkali-washed (SCl $NH_4OH/H_2O_2/H_2O$) after scrubbing, hardly any of the potassium and iron contaminants were removed, and the zinc concentration increased. That increase is thought to result from zinc in the washing liquid adsorbing onto the surface of the oxide film (SiO_2). Chemical adsorption of those metals on an oxide film surface is expected in an alkaline liquid (the weakly alkaline abrasive material and washing liquid). On the other hand, when, after scrubbing, the oxide film was washed with dilute hydrofluoric acid (DHF 0.5%), those metals were not detected in the TXRF analysis and could be removed easily by the DHF washing.

From the foregoing, a combination of scrubbing and washing with dilute hydrofluoric acid is thought to be the best way to clean an oxide film (SiO_2) after polishing.

Dainippon Screen's SP-W813-AS scrubbing and chemical washing device is highly effective in cleaning both particles and metallic contaminants.

Conclusion

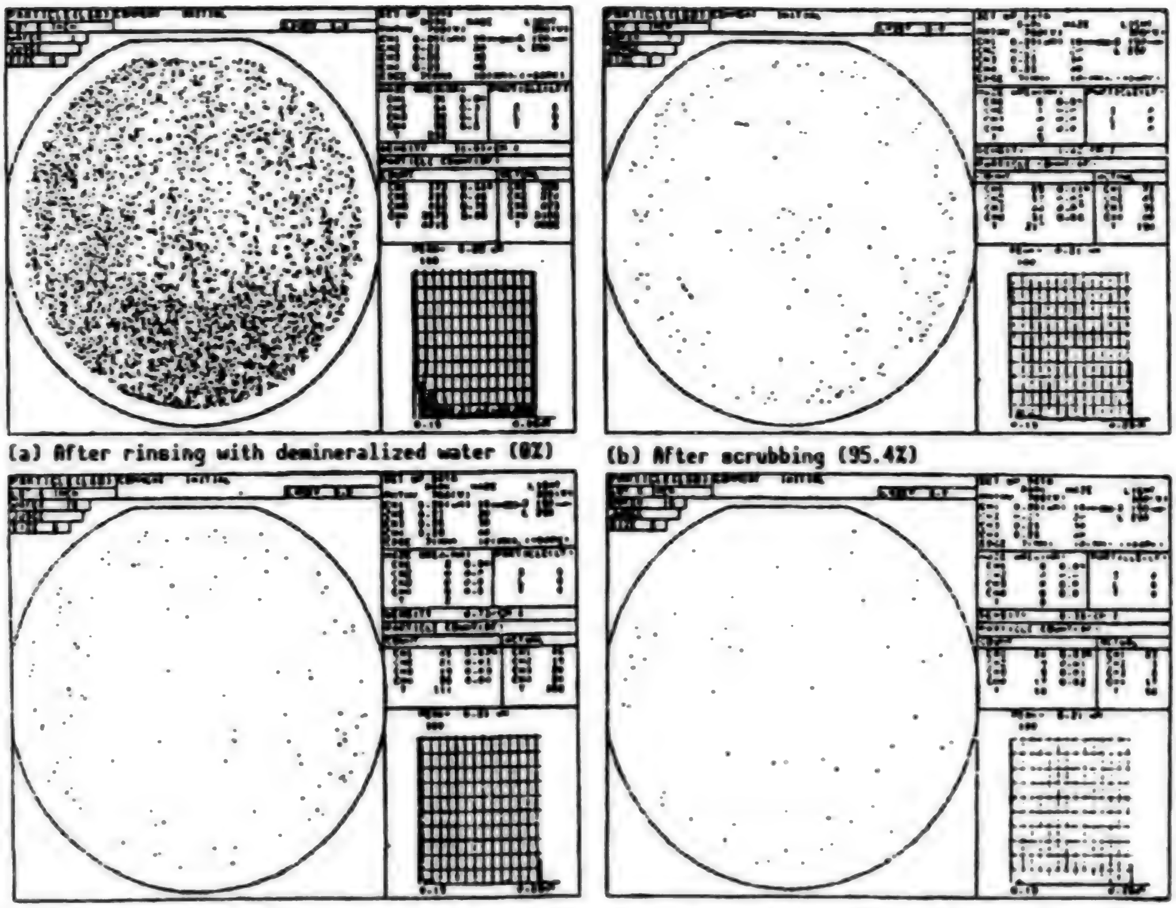
This article d[illegible]d the importance of CMP after-processing ar[illegible]ing, and the necessity and effectiveness of a co[illegible]n of scrubbing and chemical washing.

Broad applications of CMP technology are expected in LSI fabrication processes, but the optimization of after-washing is necessary for the groundwork of those applications. Applying CMP technology in LSI fabrication processes has been attempted only relatively recently, and further advances are anticipated. We also hopeto see further studies and improvements on CMP after-washing equipment.

[Boxed item, p 93] Leo Laboratory

"Wafer$_\tau$," is a noncontact, nondestructive reflective-microwave lifetime measuring device that can quickly measure a wafer's heavy-metal contaminants and the damage that occurs during processing. This article shows an example of its use in the ashing process.

The "Wafer$_\tau$ LTA-550" is the device that was used. The ashing device uses a leaf-type microwave excitation scheme. The processes carried out prior to measuring a wafer's lifetime are: resist coating, ashing, acidic resist peeling, washing, oxidation. Figure 1 shows the results of measuring the lifetimes of a wafer that was coated with resist and another wafer that was not coated with resist,



(a) After rinsing with demineralized water (0%)

(b) After scrubbing (95.4%)

(c) After scrubbing and megasonic rinsing (97.6%)

(d) After scrubbing, DHF, and megasonic rinsing (98.8%)

Numbers in ( ) show the particle removal rate when the reference is (a), after rinsing with demineralized water

Figure 5. Results of Removing Particles from CMP Wafers

with respect to the amount of ashing. The lifetime values shown are the values averaged over all points when the entire surface of a 6-inch wafer was measured at 5-mm intervals. The lifetime values decrease with increases in the amount of ashing. This is thought to be due to contamination and damage during ashing. The noticeable decrease in the lifetime of the wafer coated with resist, in particular, is presumed to be due to contaminants in the resist having been taken into the wafer. Figure 2 is the lifetime distribution when the amount of ashing was 300%. The data shows a distinctive distribution that is thought to be due to the nonuniformity of the plasma state during the ashing process.

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[Boxed item, p 94] Samukointa National Laboratory, Ltd.

Parallel-Plate Plasma Dry Cleaner, "PX-1000"

Introduction

Plasma cleaning is a dry process that does not involve the use of a special freon gas or organic solvent. In comparison with conventional cleaning methods, plasma cleaning has various features. Because chemical agents are not used, consideration need not be given to handling solvents and the waste liquid's environmental effects. And, cleaning can be done without any left-over organic residues that may affect bonding and adhesive properties in later processes.

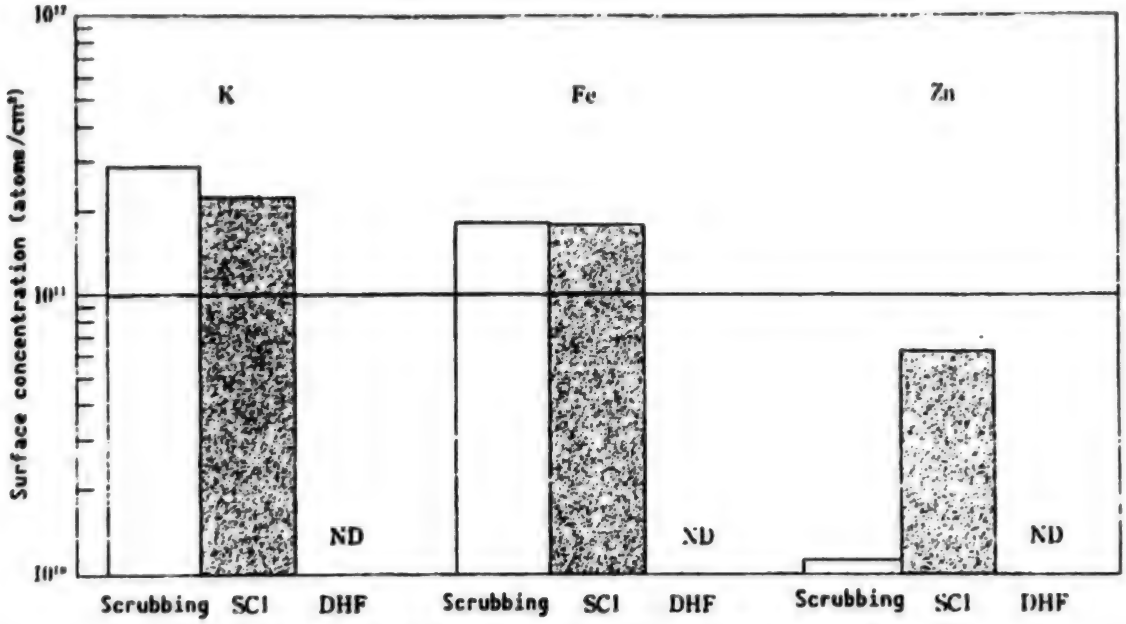

Figure 6. Removal of Metallic Contaminants (on SiO_2) after CMP

This article presents the "PX-1000" plasma cleaning system that is effective in cleaning and stripping various inorganic thin films and metals and in improving a surface's wettability and bonding properties.

Features

1. Large, Detachable Sample Trays

The system can be outfitted with up to 14 large 400-mm-wide, 450-mm-deep sample trays inside its 460-mm-wide, 460-mm-high, 610-mm-deep stainless-steel square chamber. Because the position of a tray can be varied inone-inch (25-mm) increments, samples with various shapes, from small parts to FPD square substrates, can be processed.

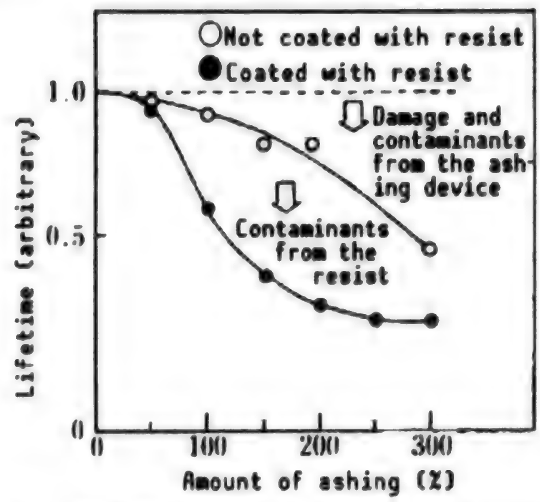

Figure 1. Relationship Between Lifetime and Amount of Ashing

2. Three Types of Process Modes

The detachable sample trays also serve as the plasma processing device's electrodes. By inserting trays at arbitrary positions, the system can assume forms corresponding to three types of plasma modes (downstream, plasma, and RIE modes). (Figure 1)

3. Process Control

One of nine previously set recipes can be selected and run automatically. A recipe can be run continuously, too.

4. Compact Design, Desktop Setup Possible

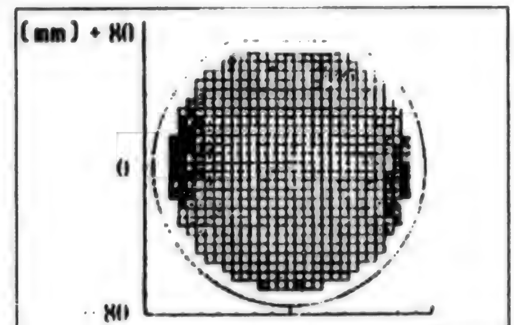

Figure 2. Lifetime Distribution After Ashing

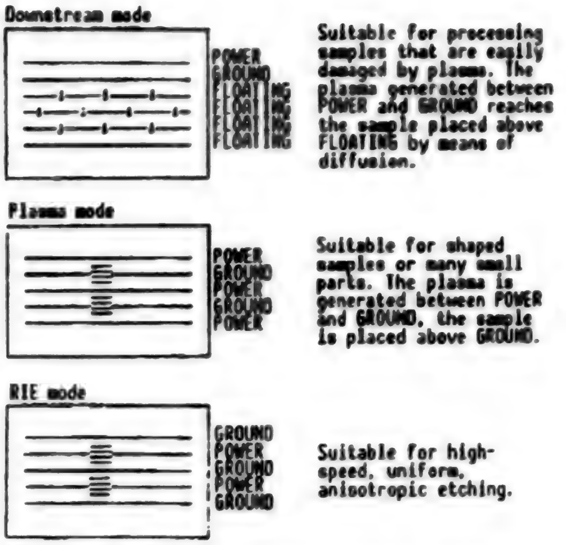

Figure 1. Three Types of Process Modes

The system is 810 mm wide, 610 mm high, and 760 mm deep, and it can be set up on top of a desk.

Etching Example

1. Ashing the Resist on a Four-Inch Silicon Wafer

The sample used in the ashing was a four-inch silicon substrate coated with OFPR-800, a posi-resist made by Tokyo Ohka Kogyo Co. The sample was post-baked on a hot plate for five minutes at 120°C. The trays were configured for RIE mode in the center part of the reactor (the upper part, the ground electrode; the lower part, the powered electrode; the sample was placed on the lower part) to form one stage with a 25-mm gap. Figure 2 shows the pressure dependence of the ashing rate. At pressures below 0.3 Torr, ion collisions get strong, and the ashing rate increases abruptly.

2. Etching Resist on a 320 X 325 Square Glass Substrate

We investigated the etching distribution within the surface of a 320 X 325 square glass substrate that was placed on top of the powered electrode. The in-plane uniformity was +/-10%, which is considerably better than the results of conventional barrel-type plasma ashing.

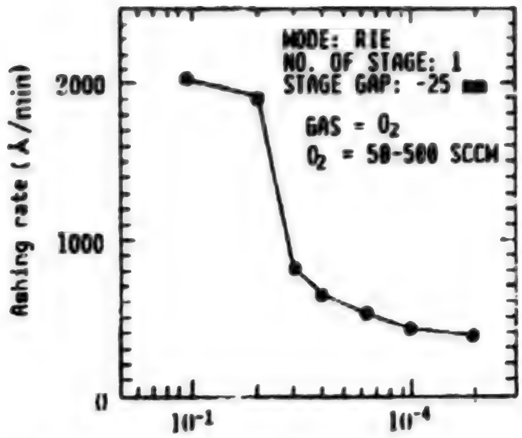

Figure 2. OFPR-800 Ashing Rate's Pressure Dependence

Conclusion

Because cleaning rate and uniformity are difficult to evaluate, we used photo-resist ashing to evaluate the PX-1000.

In barrel-type devices, there are places near external electrodes where the plasma concentration is high, which causes poor uniformity. In the PX-1000, however, a homogeneous plasma arises between two flat electrodes, and that brings about good etching uniformity. In addition to the photo-resist etching reported here, we also did silicon etching, but the PX-1000 does not have the performance needed for it to be practical in silicon etching—the values of the etching rate ranged from 5,000 Angstrom/min to about 2 μm/min.

The PX-1000 has features that conventional barrel-type devices do not have—multiple large-scale substrate processing, large-scale shaped object processing, and processing with good uniformity—and its range of applications is broad.

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Plutonium To Be Processed for MOX Fuel Overseas Before Returning to Japan

94P60284ATokyo KAGAKU KOGYO NIPPO in Japanese 13 Jun 94 p 14

[Text]

The Nuclear Power Subcommittee (Chairman, Yoshihiko Ryokaku) of MITI's Advisory Committee for Energy on the 10th presented an interim report focusing on nuclear power generation (light water reactor) and nuclear fuel recycle issues. "Environmentally-Friendly nuclear power generation" will be promoted as before. The nuclear fuel recycle policy will be maintained in order to systematically develop technology in the hope of future commercialization of plutoniuin. On the other hand, the startup of a uranium enrichment plant, the 2nd reprocessing plant, and the demonstration fast breeder reactor will be postponed in line with worldwide concern over the proliferation issue, as well as no immediate threat to uranium supplies. The plutonium that attracted so much attention when shipped on the "Akatsuki-maru" from the U.K. and France hereafter will be processed into MOX fuel in the U.K. and France prior to shipment, with the exception of that needed for research, in order to prevent nuclear terrorism.

The decisions based on two principles for nuclear fuel recycling includes;

1) To prepare for the possibility that uranium supplies will become tighter after the mid-21st century, Japan will develop the technology necessary to run plutonium-using FBRs commercially around the year 2030;

2) Japan will not stock more plutonium than it needs and will recover domestically. That returned from overseas must definitely be all consumed.

With the exception of that required for reserch and development purposes at Monju, Joyo, and Fugen, all of the 29 tons of plutonium expected to be returned to Japan will be processed into MOX fuel in the U.K. and France, providing better defense against nuclear terrorist attack than when shipping plutonium in the original form.

PNC Installs Fujitsu's Information System

94P60284B Tokyo NIKKAN KOGYO SHIMBUN in Japanese 14 Jun 94 p 10

[Text]

Fujitsu Ltd. has delivered a multimedia information system that enables more effective nuclear power plant design to the Power Reactor and Nuclear Fuel Development Corporation (PNC). The PNC's order totaled approximately 1.4 billion yen, including approximately 250 workstations and personal computers, 50 sets of the latest group software "The Collaborator," and system integration. Those items were included in the FY93 third government supplementary budget. This is Japan's largest installation of group ware using multimedia technology.

The newly installed Fujitsu system at PNC has started operation. With this system, researchers of PNC scattered in 8 branch offices throughout Japan are able to cooperate when designing nuclear power plants as they communicate with one another using multimedia technology which is capable of simultaneous imagery, voice, and documentation processing.

To date, PNC has relied on telephones and faximiles for their researchers to communicate among different offices. PNC came to realize that R&D efficiency would greatly improve with the new system because a number of researchers would be able to discuss, review, and revise documents on their computer screens simultaneously.

PNC was especially impressed with Fujitsu's group software, the Collaborator, which is capable of creating an environment in which operators can cooperate with each other as they access in real time from 4 workstations using multimedia technologies. Finally, PNC placed an order with Fujitsu for an entire system including suitable hardware and SI.

The hardware delivered by Fujitsu included 52 "S4/10 Model40" workstations, 102 "FMR5ONE/T" personal computers, and 74 "OASYS200DS" word processors. Further, as part of SI, other companies' products such as Silicon Graphics' 2 image WS, and 30 SPARC Book notebook computers by Tadpole, both from the U.S., were also included in the system.

New Project on Nuclear Energy Research Using Computer Science

94P60284C Tokyo NIKKAN KOGYO SHIMBUN in Japanese 14 Jun 94 p 6

[Text]

The Science and Technology Agency (STA) will start a project in September on "elucidation of complex nuclear energy phenomena by the computer science method." The project calls for using "computer science," which is getting a lot of attention as a third method to understand phenomena, for the basic research area of nuclear energy. The project' s objectives are to use supercomputers to analyze complex phenomena including the thermal flow phenomenon and movement of fluids which are the basic subjects of nuclear energy research, lattice movements of atoms and molecules which must be understood for property research, and vortex phenomena of superconducting materials, which cannot be understood through conventional experiments and theories and could open up new research areas. The Power Reactors and Nuclear Fuel Development Corporation (PNC, Director Takao Ishiwatari), the Japan Atomic Energy Research Institute (JAERI, Director, Shozo Shimomura), and the Electrotechnical Lab (ETL, Director, Sakutaro Tomiyama) will participate in the project. The research is scheduled to last 5 years.

The project will be limited to basic new research on nuclear energy. It is part of the 'computer science' project under which a number of researchers at various research

institutes will try to solve problems too difficult for a single institution to manage by sharing a wide range of knowledge with each other via supercomputers. The research will cover materials for nuclear power reactors, simulation of structural materials with frcture strength/heat history, and the structural problems of brittle materials.

Particularly problems such as those of particles and fluids and structures and fluids, which are impossible to understand through experiments and theories will be tackled with supercomputers. For example, JAERI will seek solutions of complex phenomena using particles and sample models. More specifically, the research subjects will include thermal convection generated in reactors, steam bubble generation mechanisms, and turbulence flow. It should be useful for understanding superconducting phenomena as well as helping discover new phenomena. Also PNC will pursue the understanding of complex engineering phenomena of fluids and structures, which is required for reactor design, and the complex phenomna of the cores of fast reactors. ETL will conduct research on applications of supercomputers. The project will also include the development of special computer boards and hardware for animation display devices.

Hot Cell Examination at Radioactive Waste Vitrification Facility

94P60284D Tokyo KAGAKU KOGYO NIPPO in Japanese 15 Jun 94 p 1

[Text] The Power Reactor and Nuclear Fuel Development Corporation (PNC) will run hot cell tests this coming fall using actual waste at the "Tokai Vitrification Facility" (TVF) where high level radioactive liquid waste generated during the separation process at the Tokai Reprocessing Plant is vitrified. Construction of the TVF was completed in April 1992. Since then PNC had been running cold cell tests using a non-radioactive liquid waste mockup in order to confirm safety for running hot cell tests. The cold cell tests are expected to be completed around this summer. Official tests are about to begin to produce actually vitrified pieces.

TVF is the facility where high level liquid waste stored at the Reprocessing Plant of PNC's Tokai Works is vitrified (liquid waste and glass materials are mixed into stable and easy-to-handle solid form). The construction cost of the TVF totaled 38 billion yen. The process of this facility includes:

1) pre-processing, such as enrichiment of the liquid waste when it first arrives;

2) melting of radioactive waste and glass materials;

3) injection of molten glass into vitrifying containers for storage;

4) treatment of gas emitted from reactors such as molten-salt reactors.

These integrated operations are carried out in a giant stainless container (solidification cell). All of the work in the cell is done by remote control using 2 sets of dual-armed manipulators.

Processing capacity for the high level liquid waste is 0.35 cubic meters per day. It takes a day and a half to make one 110 liter solidification cell. Vitrified pieces after the processing are stored in the pit of the cell and kept air-cooled.

HTTR Equipment Installation Begins

94P60284E Tokyo KAGAKU KOGYO NIPPO in Japanese 15 Jun 94 p 1

[Text]

Construction of a hot temperature test engineering reactor (HTTR) at Oarai Research Establishment has been under way under the supervision of the Japan Atomic Energy Research Institute (JAERI). targeting FY98 for its initial criticality. JAERI will start installing reactor equipment on the premises officially in FY94. HTTR is a high temperature gas reactor type experimental reactor which will produce the world' s first 850-950°C helium gas (coolant). Now that construction of a reactor building and installation of a containment vessel have been completed, JAERI is ready to ship and install cooling system equipement such as a reactor pressure vessel and pressurized water cooling equipment. The structural framework inside the reactor which is the heart of the HTTR is being assembled at the factory and its assembly tests have officially begun this fiscal year.

This high temperature reactor is a new type of reactor which has been receiving a lot of attention for industrial use because it can provide a high temperature, concentrated energy source. Helium gas which is extremely stable even at high temperaturers will be used as a coolant which carries the heat out of the reactor. Also "graphite" which is highly resistant to both radiation and high heat will be used for the structural material of the core. HTTR's objectives are to collect data for future commercialization of high temperature gas reactors through irradiation tests for core materials and tests to vent high temperature gas from the reactor.

Construction of HTTR started in March 1991 with anticipation of completion in FY98. Fuji Electric will be in charge of design and production of the reactor's framework which is scheduled for shipment beginning in April 1995. At present, performance tests are being conducted at Fujitsu's Kawasaki plant as assembly of the entire framework of about 6 meters in diameter, about 8 meters in height, and about 300 tons in total weight is being made. The assembly tests are expected to be completed in October 1994. After completion of the tests. the framework will be dismantled and prepared for shipment.

Advisory Committee for Energy Reports on LWR Safety Measures

94FE0732A Tokyo KAGAKU KOGYO NIPPO in Japanese 30 May 94 p 14

[Text] The Nuclear Power Subcommittee of the Advisory Committee for Energy which established a subordinate unit, "Light Water Reactor (LWR) Working Group"

(chairman of its investigation committee: Tsutomu Inoue, director of Nuclear Power Generation Technology Organization), and which has been studying LWR safety measures, recently put together a report in draft. According to the report, the committee aims at the maintenance and improvement of existing and new reactor safety and reliability. With the existing reactors, the committee will work on the enforcement of the measure developed to deal with severe accidents, the problems of aging reactors, and reduction in manpower. As for the newly-built reactors, the committee advocates the establishment of an improved type of LWR as on a more permanent basis as well as the advancement of LWR technology. These proposals will be incorporated into the Nuclear Power Subcommittee's interim report to be submitted as early as in June.

Nuclear power generation currently in operation involve 48 reactors with LWR's playing a central role, and generating 3,838kW. This output constitutes approximately 31% of the total amount of electric power generated (based on the 1993 figures). Since the actual use of plutonium in fast breeder reactors most likely will not be achieved prior to 2030, LWR will play a major role over a long period of time.

Consequently, the safety measure and public acceptance aspects of LWR increasingly are becoming important in the future. Bearing these in mind, the LWR Working Group (WG) has continued examining the problems from this standpoint. In addition to the past safety measures, WG is seeking improved safety by implementation of the severe accident measures.

As for the problem of aging reactors, the committee's report is stressing the importance of ensuring complete safety by raising facility maintenance standards and undertaking R&D of related technologies so that the latest technological knowledge will be utilized in dealing with existing reactors as well as in evaluating results of periodic safety [reviews] conducted by the electric business sector. The government moreover considers the establishment of an overall facility management policy by the electric business sector essential.

As for reduction in manpower, the report proposes the industry to rethink its basic approach for achieving sophisticated periodic inspection while working on advanced operational management entailing periodic inspection. It also proposes shorter intervals between periodic inspections with the collection of safety data as a prerequisite, and consideration of incorporating long-range cycle operations. In addition, as a part of measures dealing with existing reactors, the report is urging the industry to prepare for proper handling of reactors marked for retirement as well as treatment of nuclear wastes.

As for newly installed reactors, the report points out that before doing anything else, it is essential to develop and to stay with advanced boiling light water reactor (ABWR) and the advanced pressurized water reactor. It is also pointed out the importance for Japan of raising the level of safety inspection on the basis of the advancement made in standard designs. Based on the idea that advanced light water reactor technology represents "the type of nuclear power generation technology gentle to people," the report points out, research in future light water reactors must be conducted, fully taking into consideration prevailing international trends. Appropriate action in this connection will be for governmental, electric enterprising, and manufacturing sectors to undertake joint research for a period of approximately 3 years and to use its findings in planning for advanced measures to control future light water reactors.

Moreover, PA measures of the government and electric enterprise sectors targeting the general public, in addition to the use of mass media, include efforts to disseminate information through meetings with those in the educational field and to foster public understanding of how to handle energy and nuclear power through greater exposure provided through education. The committee report also seeks expanded PR activities to create interest in nuclear energy among women.

Actinide Recycle Research To be Promoted

94FE0732B Tokyo NIKKEI SANGYO SHIMBUN in Japanese 1 Jun 94 p 5

[Text] In order to decide on the ways in which research in "actinide recycle," designed to burn long-life radioactive wastes by mixing them with plutonium, will be carried out, the Atomic Energy Commission of Japan (JAEC) (Chairman: Mr. Ohmi, Director General of Science and Technology Agency) soon will begin deliberations participated by the Special Subcommittee on Nuclear Fuel Recycle (subcommittee chairman: Hiroshi Murata, director of Atomic Energy for Promotion of Culture Foundation). The deliberations will be focused on the contents of a new test reactor which will be used as a research facility.

Actinide recycle will be incorporated into the long-range plan for development and use of atomic power, a project which soon will be approved officially, as a major item of the project's R&D themes. According to the sectional committee of the special long-range planning subcommittee's report issued not long ago, "Power Reactor and Nuclear Fuel Development Corporation (PNC) and Japan Atomic Energy Research Institute (JAERI) will aggressively pursue the actinide recycle R&D."

The Special Subcommittee on Recycle also will study the actinide recycle research setup and required test facilities. The question of need for test reactors also will be discussed, which means that construction of a new reactor will become a topic of a debate in the atomic energy field for the first in a long time. The subcommittee will spend approximately one year to produce its conclusion.

The actinide recycle is a star of the advanced technology which uses fast breeders. It is designed to extract and recycle americium and neptune, produced by combustion of nuclear fuel together with plutonium. Since plutonium

is handled with other elements and not alone, it will not be diffused. In addition to this merit, the actinide recycle offers the possibility of simplifying reprocessing.

Toward New Ultra Heat Resistance Alloy Application for Reactors

94FE0732C Tokyo KAGAKU KOGYO NIPPO in Japanese 2 Jun 94 p 1

[Text] Japan Atomic Energy Research Institute (JAERI) and Japan Welding Rod (head office: 1-13-8, Ginza, Chuo-ku, Tokyo-to), a stainless and specialized steel welding material manufacturer, will jointly undertake the development of welding technology beginning 1994. Their objective is to produce a type of new super thermal resistant alloys which can withstand a high-temperature gas (HTTR) on an industrial scale in actual situation. The materials in question are Ni-Cr-W (nickel-chrome-tungsten) system super heat resistant alloys. These materials are said to be anti-corrosive, has a great deal of strength, and yet easy to work with, the characteristics essential to the structural materials of HTTR, a new reactor designed to supply extremely high-temperature heat of 1000°C, required in producing hydrogen. In order to realize the practical utilization of this new alloy in reactor materials, it was necessary to deal with the problem of welding techniques, such as those encountered in the development of welding filler materials which can join base materials together with high precision. Under the 3-year plan, the joint effort will be directed to the establishment of the welding technology.

HTTR is equipped with the ability to draw out directly high-temperature heat from nuclear reactors. For this reason, its use in the industrial field, such as hydrogen manufacturing, requiring a large amount of heat, is anticipated. One of the technical problems which must be dealt with when constructing HTTR is the development of materials meeting its requirement. Helium gas, a cooling material, can draw approximately 1000°C heat from the nuclear reactor. Piping metals, through which such a high-temperature heat is conducted, needless to say, must be able to withstand hot temperature for a long period of time.

Approximately 10 years ago, JAERI undertook R&D of super heat resistant alloy for use in HTTR. The initial target performance set for the alloy consisted of the following:

(1) possesses a high degree of strength under hot-temperature conditions;

(2) possesses an excellent anti-corrosion property in a helium gas;

(3) can be worked to make a nuclear reactor's heat exchanger tube;

(4) can be used in welding.

In developing the alloy, the first task to be accomplished was to optimize the contents of its base elements, Cr and W. After the chemical composition which satisfies these four performance requirements was discovered and proposed, the alloy was produced in varied chemical compositions and repeatedly tested, and finally researchers reached a point where they felt that they could begin developing a new alloy.

In order to reach the final step of achieving practical application of the new alloy, it was necessary to pass successfully the targeted technical performance tests in welding. That is why JAERI has decided to make this a joint undertaking at this time. It will propose the development of chemical composition which satisfies the requirements of a filler material by first finding an element highly resistant to weld cracking. The joint R&D team, moreover, plans to accumulate knowledge and information concerning thermal processing conditions when creating filler materials.

"High reliability is a must for" structural materials of nuclear reactors, constantly exposed to exceedingly severe conditions produced by high temperatures and mass irradiations (JAERI). The industry has begun investigating the possibility of applying this new alloy to a heat-resistant material used in fuel cells. Its application in non-nuclear power field, therefore, is also attracting attention.

MITI's Agency of Natural Resources and Energy Promotes Public Information on Nuclear Power Generation

94FE0732D Tokyo KAGAKU KOGYO NIPPO in Japanese 2 Jun 94 p 12

[Text] MITI's Agency of Natural Resources and Energy, which received the Advisory Committee for Energy's interim report to be issued on June 10, will put in place a new system through which "public information on nuclear power generation" will be disseminated.

By promoting wider dissemination of information on nuclear power generation among the general public, the agency attempts to raise the general public's levels of confidence in safety of nuclear power generation while dispelling any misgivings the public may have. The Atomic Energy Public Information Service Unit will serve as MITI's window in this connection. Receipt of requests for information and access to materials by the general public will be put into effect after "Atomic Energy Public Information Service (temporary designation)," has been established within the Atomic Energy Technology Organization, a corporation.

While nearly 70% of Japanese understands why nuclear power generation is necessary, only 40% is convinced of its safety, reflecting the low level of confidence the public has regarding information disseminated by the government and electric industrial sectors. In order to make the majority of people understand and accept the fact of nuclear power generation, in addition to the existing explanation of "safety and necessity" of nuclear power generation, it is essential that people will be made to

recognize the fact that all pertinent information is made public by both the government and the industry. From this standpoint, based on the report of the Agency of Natural Resources and Energy's Atomic Energy Sectional Committee, MITI has decided to make information on the safety of nuclear power generation available to the public through a new system.

Based on the standard procedures for opening government administrative information to the public, the new public information service will allow public to access reports dealing with the past accidents and breakdowns associated with nuclear power generation on the assumption that this is the area in which the public is keenly interested. More specifically, those which can be accessed by the public at open stacks are reports on equipment breakdowns associated with nuclear power generation and results of commissioned investigative research (either in summary or published editions.)

Those made available in response to individual requests are applications for construction plan (modified) permits. Since these permits are voluminous, requiring a vast amount of time to mask, what they plan to do is to select a model plant beforehand and, even if no request has been received, to go ahead with masking so that the document will be made available to the public. The permit application for nuclear reactor construction (modification) already has been made available for public viewing.

Other than permit applications, if a request is received for a legal or public-notification-related document, for instance, the government will do its best to mask it so that the requested document may be made available for the public. The targeted legal documents, under MITI's jurisdiction, are based on "law concerning regulations imposed on nuclear raw materials, nuclear fuel materials, and reactors" and "Electric Enterprise Law," and specifically related to the safety aspects of nuclear power generation.

The documents in the following categories, however, will not be open to public:

(1) the type of documents which will impede nuclear nonproliferation as well as protection of nuclear materials if opened to public;

(2) the type of documents which will create problems in terms of a competitive position of a license applicant and property right protection involved if documents are made public;

(3) its availability to the public is detrimental from the standpoint of protection of individual information;

(4) other types of information which can be treated as "closed" in accordance with the rules governing the opening of information to the public and which will create problems if they were to allow access by the public. Moreover, if information designated as "closed" constitutes a large part of a document, that document sometimes will not be open to the public.

With June as a target month, the Agency of Natural Resources and Energy will begin providing public information service under the new setup.

Japan, Canada To Expand Joint Research on Waste Underground Disposal Research

94FE0732E Tokyo KAGAKU KOGYO NIPPO in Japanese 6 Jun 94 p 14

[Text] On the afternoon of June 3, the Canadian time, (on the morning of June 4, Japanese time) in Ottawa, the Power Reactor and Nuclear Fuel Development Corporation (PNC) concluded an agreement with Canada's AECL ([Atomic Energy Corporation]) concerning their joint R&D plan in the field of radioactive waste management. Underground disposal is one of the methods ensuring safe long-range isolation of high-level radioactive wastes from our environment. PNC and AECL agreed to use geochemical and artificial barrier methods to conduct underground disposal research designed to examine the technical possibility of the above concept. Their cooperative plan includes test research employing AECL's underground research facilities, indicating further development in the Japan-Canada cooperation efforts.

AECL's [White Shell] Research Institute is equipped with underground research facilities with the maximum depth of 420 meters, where research in underground disposal of spent fuels is being conducted. Since 1986, using a fracture zone in a crystalline rock, PNC and AECL have been developing jointly a method of examination and analysis designed to study the structure and distribution (hydraulic properties) of cracks in the rock. Japan and Canada had been conferring on further development of such cooperative research efforts dealing with underground disposal of nuclear waste. This has led to the signing of the agreement to expand their cooperative relationship into a new research area. The formal signing of the agreement took place between Taguchi, PNC's deputy director, and [Toggerson], AECL's head of research enterprise.

The scope of cooperation includes the following areas:

(1) Test research of the underground from the standpoint of geochemistry, the characteristics of the rock, hydraulics, and artificial barriers and their [uzumemodoshi];

(2) Techniques for measuring underground layer characteristics;

(3) Research concerning material behavior and migration of radioactive nucleides;

(4) Evaluation of disposal system performance;

(5) Exchange of information on PR activities.

The method relies on cooperation through the exchange of opinions, an exchange program for receiving and sending experts and researchers, and joint research. The agreement covers a period of 5 years, from the date of signing the agreement.

Japan's basic policy for dealing with the high-level radioactive waste disposal is to store radioactive wastes for a period of 30 to 50 years in order to cool them, and ultimately seal them in the underground a few hundred meter deep. For this reason, the problem which must be dealt with first by researchers is to prove both scientifically and technically the effectiveness of the underground disposal method in question without tied it to a particular region or a type of rock.

International Framework Presented for Plutonium Use

94FE0732F Tokyo NIHON KEIZAI SHIMBUN in Japanese 11 Jun 94 p 13

[Text] A debate on the creation of an international framework for maintenance and use of plutonium, an issue which came to the fore as a result of the dismantling of nuclear weapons and commercial use of nuclear energy, is nearing a climax. The objective of the international framework is for each country to make public voluntarily the ways in which it uses plutonium so that the degree of transparency in this respect will be enhanced. This is for the most part aimed at extending the Nuclear Non-Proliferation Treaty (NPT), due to expire next spring, as smoothly as possible. However, each country has its own idea of what the content of the international framework should be. For instance, Europe is unwilling to go along with the U.S. which proposing a new measure for elimination of surplus plutonium.

On 4 June 1994, the second meeting was held at the British Mission in Vienna on "examination of the international framework concerning plutonium use." The meeting was attended by the government representatives of the five nuclear states, viz., the United States, Great Britain, Russia, France, and China, and four plutonium-for-peace countries, viz., Japan, Germany, Belgium, and Switzerland.

Pursuit of Rigorous Management

At the meeting, the U.S. delegation, maintaining that "accumulation of isolated plutonium for storage, regardless of whether it is for military or commercial use, directly leads to the threat of nuclear proliferation," proposed an effective measure designed to suppress any plutonium generation for the future.

In September 1993, the White House expressed its determination to suppress worldwide accumulation of plutonium for commercial use, and to place the plutonium generated by the dismantling of its nuclear weapons under the IAEA (International Atomic Energy Agency) inspection rather than placing it solely under its own management.

It can be said that this latest proposal "is in line with the basic U.S. policy pursuing rigorous management of plutonium." (Japan's Science and Technology Agency).

Delegates from Great Britain and France, the countries which advocate use of plutonium for the benefit of people's livelihood and which possess spent fuel reprocessing plants, however, raised unanimous objection to the U.S. proposal, saying "accumulation of plutonium itself will not present any problems."

In the case of Great Britain which discontinued a full-scale use plan involving a fast breeder, the generation of surplus plutonium is something which cannot be avoided. France, on the other hand, is proceeding with plutonium combustion plan using a light water reactor. As such, it is expected to generate less surplus plutonium, and, therefore, is not quite as concerned with the matter of surplus plutonium. Consequently, it has a passive attitude insofar as curbing the use of plutonium is concerned.

Problems of Surplus Plutonium Most Serious for U.S.

Since Japan's policy is not to own surplus plutonium, it is entirely possible for Japan to accept the U.S. proposal. However, Japan's policy of achieving a demand-supply balance is a unique measure designed to make its plutonium management more transparent. However, Japan felt that if this rule is generalized, regulatory activity may intensify, and certainly that would not be welcome. Methods of handling surplus plutonium became a topic of debates at the conference on "international plutonium storage" held from the latter half of the 1970's to the 1980's. Since participating countries did not agree on the definition of surplus plutonium, it eventually brought down the conference.

It was the United States which proposed the "control of surplus plutonium." Ironically, it was none other than the United States which had the extremely serious problem of surplus plutonium brought about by its nuclear dismantling. The reason for this was that, unlike other countries, the United States abandoned the plan to use plutonium for the benefit of people. Also completely discarded were its R&D projects dealing with plutonium combustion.

Mounting Serious Efforts for Negotiations

At a recent conference, regarding a disposal method for plutonium produced by nuclear dismantling, the United States announced that it was debating whether to burn plutonium in a reactor on a one-time-only basis or to dispose it with an underground disposal method by vitrifying plutonium. In actuality, however, the United States still is in the dark as to how to achieve either one of the methods.

In order for each country to make public how it is actually using plutonium, Japan proposed at the recent conference a uniform format of presentation. Although it was Japan's wish to take the discussion to a more specific area of how periodic announcements should be made, it appears now that the conference debate will be focused on the question of how to handle the U.S. proposal concerning surplus plutonium.

Today, when the NPT system is made shaky by the possibility that the Democratic People's Republic of Korea (North Korea) may possess nuclear capability, if the objective of creating the international framework is to make countries using plutonium "straighten" themselves, tightening regulations imposed on plutonium use cannot be avoided. It appears that haggling over the degree of regulatory control imposed on the countries will be more intensified.

Technical Efforts To Reduce Nuclear Power Generation Cost

94FE0732G Tokyo NIKKAN KOGYOI SHIMBUN in Japanese 17 Jun 94 p 19

[Text] Because of its stable supply capability and cost-effectiveness, as well as from the standpoint of environmental protection, electric power companies are pushing the development of nuclear power generation to ensure a base supply source, on the assumption that it is safe. In the case of Tokyo Electric Power, the company is using the U.S.-developed BWR (boiling water reactor). A total of 14 of these reactors currently are in operation at the company's Fukushima I and II NPP (nuclear power plants) as well as Kashiwazaki-Kariwa NPP, generating a total of 13.496 million kW, or 25% of Tokyo Electric Power facilities' total output.

Generally speaking, although the public increasingly is becoming aware of the need for nuclear power generation, a sense of uneasiness still persists, and this is plainly reflected in the difficulties utility companies are facing in securing plant construction sites. Since the ratios of both investment and construction costs per power generation price cost are high, companies must work hard to improve efficiency and cost-effectiveness. Cutting construction cost, therefore, is extremely important.

In order to solve this problem, Tokyo Electric Power employed the world's first advanced boiling water reactors (ABWR) at its Kashiwazaki-Kariba NNP's units Nos. 6 and 7 to reduce their construction unit costs. The ABWR can increase output from the existing model's 1.1 million kW to 1.35 million kW. Furthermore, since recirculation pump is internal, externally installed recirculation system of nuclear reactor cooling material can be eliminated. This not only enhance the safety of reactor operation but also capacities of reactor containment and building can be reduced substantially. As a result, approximately 24% reduction in total building volume can be achieved.

According to the company's estimate, this will make it possible to reduce a single-unit construction cost of equipment Nos. 6 and 7 by approximately 15%. At the same time, use of a large-volume turbine will improve thermal efficiency from existing turbine's 33.4% to approximately 34.5%.

Moreover, since nuclear power plant construction requires a vast amount of construction materials as well as strict quality control, in comparison with thermal power plant construction, it takes almost twice as much time, viz., 5 to 6 years. Especially at Kashiwazaki-Kariba site where in winter the Japan Sea climate with wind and snow requires longer construction time in comparison with that of plants located on the side of the Pacific Ocean, (Fukushima I and II NPPs). This adds to construction costs because of increase in interest debt.

For this reason, from the construction of its No. 1 unit on at Kashiwazaki-Kariba, Tokyo Electric Power has made every effort to maximize construction efficiency and to improve design plans, viz., reducing the building volume, so that construction time can be shortened. As for realizing construction work efficiency, the company employed the "all weather construction method," designed to raise winter-time construction efficiency to equal that of summertime and developed the "Large Block Construction Method" to raise summertime construction efficiency. A first method was applied in building Unit No.6, and a second one in constructing Unit No. 7.

Although construction (from a survey of a rock bed to fuel loading) of Unit No. 1 took 54 months, with that of Unit No. 2 and subsequent constructions, the company was able to shorten construction time by from 6 to 12 months. The reduction in interest payments, if the interest rate is 5%, range from approximately ¥ 3.6 billion to ¥ 7.2 billion. For instance, the construction time of Unit No. 6, whose operation is scheduled for December 1996, is 42.5 months according to the plan. The shortened construction time contributes to reduction in at-site operating costs.

In the meantime, various electric power companies are attempting to build on a common lot sharing an electric source. The first case in point, in the field of nuclear power generation, is a Totsu Site (Tokyo and Tohoku Electric Power Companies) in Aomori Prefecture. They have succeeded in reducing construction cost of approximately ¥ 4 billion. Both companies were planning to build two 1.1 million kW units each. If in the future the common use of power plant facilities should become feasible, companies can expect further reduction, amounting to a few billion yen in construction and operating costs. In addition, the companies will benefit from a secondary effect of effective use of a building lot as a result of the intensive use of the facilities.

Tokyo Electric Power's future policy with respect to electric sources and key transmission systems is "to conduct exhaustive study of cost reduction measures for each individual case beginning with the selection of a site" (Managing Director Ken Taneichi). In addition, as an example of cost cutting, purchase of parts from abroad is cited. The company ordered circulating water pipes for Kashiwazaki-Kariba Units Nos. 6 and 7 by making an international bid to the U.S. company, [Tymeck].

Sumitomo Electric Industries Experiments with Synchrotron Radiation

943FE0669B Tokyo NIKKEI SANGYO SHIMBUN in Japanese 25 Apr 94 p 5

[Text] Sumitomo Electric Industries will bolster research activity of its Harima Research Laboratory (Kamigun-machi, Akaho-gun, Hyogo Prefecture), experimenting with synchrotron radiation (SR). Its plan is to add three more beam lines ([a beam path emitting lights]) to the present one by 1995, thereby widening the scope of its research themes. Harima Research Laboratory is the first corporate laboratory to move into Harima Science Park City. Taking this opportunity, the company hopes to strengthen joint research setup with its university.

SR is an extremely powerful light emitted at the time of electron acceleration to almost the speed of light and changing of directions. It can be used in medical diagnosis and material analysis which thus far had not been possible. It is appropriately called "magic light," producing the basic technologies of the 21st century. Harima Research Laboratory which Sumitomo Electric Industries established in January of this year, is its ninth corporate research laboratory, and is equipped with a compact SR system designed to derive lights by accelerating electrons to 100 million electron volt in terms of electronic energy.

Although only one beam line is used in the present setup, by May 1994, another line will be added. In addition, one more line will be installed within this year, with a third line added by 1995. Since it costs a few tens of million yen to install a new beam line, the amount of company investment is estimated to reach somewhere between ¥100 million and ¥200 million.

Thus far, a research theme using SR had not gone beyond the development of microstructure processing method. With the additional installation of beam lines, however, the company plans to broaden the scope of the research theme to include development of thin film formation technologies and analytical techniques designed to probe materials' surface state and internal structures.

The Science Department of Himeji Technical University in the Harima Science Park City, where Harima Research Laboratory is located, is known for its interest in SR. Sumitomo Electric Industries already has requested the university to conduct research to find whether it is theoretically possible to fabricate a single-crystal thin film using optical CVD ([chemical vapor phase epitaxy]). In the future, the company will continue to cooperate with the university within the framework of joint research.

Moreover, Sumitomo will explore the cooperative relationship with the "SPring-8," the world's largest SR facility currently under construction.

JAREI's Progress with BTA Prototype Proton Accelerator

943FE0667C Tokyo KAGAKU KOGYO NIPPO in Japanese 11 Apr 94 p 1

[Text]

Japan Atomic Energy Research Institute (JAERI)

A full-scale development of the ETA ([high intensity proton accelerator]) element technology, which has been attracting attention as a promising technology, designed to convert elements with a long half-life contained in high-level radioactive waste into non-radioactive nuclides, will start this year. JAERI has undertaken the development of ETA in order to reduce waste treatment loads. As its first step, the JAERI's plan calls for the construction of a BTA ([an accelerator used in technical development]), a part where radiation enters in ETA, so that an acceleration test of proton beams which decay radioactive nuclides can be carried out. For this year, a test using a reduced-scale BTA model will be undertaken. For the subsequent year, JAERI will begin designing BTA, so that hopefully by 1997 its construction can begin.

To Start with Prototyping of Model for Incoming Radiation Part

High-level radioactive wastes discharged by atomic reactors contain, in addition to strontium which can be used as a thermal or radioactive source, rare platinum group elements, which can be used as a catalyst or electrode, and transuranic elements with a long-life span. Of several attempts to be mounted to deal with those elements separated by chemical property, one targeting transuranic elements, namely, an attempt to convert them into a short-life stable matter by irradiating protons with neutrons in an accelerator or mono-fuel combustion fast reactor, is attracting attention. Such research, dealing with decay processing technology and already proposed by Japan to OECD/NEA, has been generating activities within the "Omega Project," an international cooperative project.

The decay processing method utilizing ETA entails the following steps: First of all, non-critical reactor core which uses transuranic element as fuel is irradiated with high-energy protons obtained from the accelerator, as a result of which, transuranium nuclei colliding with protons are destroyed releasing a large number of particles and converting them into entirely different matters. At that time, the energy generated by the destruction of nuclei can be used in power generation.

BTA is configured with an ion source producing [neutral element] ions (protons); a high-frequency quadrupole [liniack], a first-stage accelerator designed to focus on high-density beams; and a drift-tube [liniack] (DTL), designed to accelerate further the focused beams. When the "high beta [liniack]" used in the high-energy zone in the latter stage is connected to BTA, we then have a main ETA unit. The plan for 1994 is to install each main equipment of a compact version BTA at JAREI's Tokai Laboratory and to proceed with beam acceleration tests. The scale of BTA in terms of cost is approximately ¥3 billion. Ultimately, ETA will have the capability of accelerating protons to obtain 1.5 billion electron volt energy.

It will be possible to utilize powerful neutrons produced by ETA in a wide area of research encompassing the fields of physics, chemistry, biology, and medicine. For this reason, JAERI wants to make ETA as a shared facility open to research organizations both here and abroad.

Multimedia LAN Services

94FE0555A Tokyo NTT R&D in Japanese 10 Feb 94 pp 69-76

[Article by Kensaku Kinoshita, NTT Telecommunication Networks Laboratories]

[Text]

Abstract

In this article I discuss the current status and future developments of multimedia LAN services that will utilize the ATM-LAN as the core technology for broadband networks. First I look at the current status of LAN. Next I explain ATM, which will form the core of a future network, and its advantages. Then I present an outline of the ATM-LAN and discuss development of the broadband networks that will include ATM-LANs, and their user services. Finally, I introduce several examples of multimedia LAN services and present topics for future discussion.

1. Introduction

The history of telecommunications, based mainly on the telephone, stretches back more than 100 years, but recently local network systems to support corporate activities have shown remarkable growth, and this have led to information processing and telecommunications on the individual level.

During this time information processing performance has made remarkable progress, and in the past twenty years it has grown 100 times faster than telecommunications performance. Moreover, the recent trends toward downsizing and open systems that have resulted from more sophisticated workstations will require telecommunications networks with increasingly higher capabilities.

When we look at business activities, we see that terminals have become more sophisticated in response to demands for greater flexibility, higher capabilities, greater speed, and more economy of labor, and there are now many cases in which there are multimedia telecommunications environments in use that consist chiefly of data and images. Moreover, expectations are increasing for telecommunications systems that will function as corporate infrastructures to enable the rapid, high-function transfer of data, not only as a means to utilize these kinds of multimedia telecommunications environments, but also to provide a more humane working environment and decentralize the processing of vast quantities of data.

NTT has been working on development of the ATM-LAN as a telecommunications system to meet these expectations.[1-5] The ATM-LAN is expected to play a major role in the future as a front-end processor for wideband networks. Therefore, it is important that ATM-LAN service develop as a user service for wideband networks.

This article explains the current status and future prospects of multimedia LAN service as a wideband network service based on ATM-LAN technology.

2. Current Status of LAN

First I will outline the current status of LANs. At present large-scale LANs consist of two types, branched systems and trunk line systems. The main types of branched LANs are the 4 Mb/s token passing ring LAN and the 10 Mb/s CSMA/CD LAN, and the main type of trunk line LAN is the 100 Mb/s FDDI (Fiber Distributed Data Interface).

Moreover, HIPPI (High Performance Parallel Interface), which can realize transfer at speeds up to 1.6 Gb/s, has been selected as the standard high-speed computer interface for multimedia LANs by ANSI (American National Standards Institute). In addition, for the transfer of non-data media such as audio signals over the LAN, a hybrid format that has a circuit switched synchronous channel for audio signals is being studied and put to practical use as one means of realizing multimedia on the LAN.

We can expect speeds to become faster in the future, and it is predicted that FDDI will be used for branched LANs and FFOL (FDDI Follow-On LAN), which has gigabit-class transfer speeds, and ATM-LAN will be used on trunk line LANs.

Each of these LAN setups will be suitable as a means for realizing high speeds, multimedia, and multiple services, but the ATM-LAN is being vigorously developed because it is a format with high B-ISDN connectability and abundant expandability.

ATM Networks

This section explains ATM as the core technology of future networks and explores its advantages.[6]

3.1 ATM Features

First I will look at the technical features of ATM network systems.

ATM (Asynchronous Transfer Mode) is a data transfer format that uses a 53-byte fixed-length packet called a cell as a basic unit. The 5-byte header of the 53-byte packet includes the destination and other information, and the remaining 48 bytes contain the data. This is a transfer mode characterized by the fact that it uses self routing, in which the destination identity is switched at high speeds by hardware, and the intervals between cells for the same address are asynchronous, so it is called ATM.

The destination address in the ATM header is hierarchical, so both virtual pulses (VP) and virtual channels (VC) can be used. Because ATM can deal with multiple VPs and VCs simultaneously, it can respond to data at various communication speeds with a single switch, and it makes effective use of the transmission band through statistical multiplexing.

3.2 Advantages of ATM Networks

There are many advantages to networks that utilize the features of ATM.

From the standpoint of services, first of all ATM enables simplification of wiring facilities by creating physically uniform interface conditions that are independent of the speed of the data. Second, by selective use of hierarchical VPs and VCs, it enables high-speed transfer of multimedia communications by integrating continuous data such as audio and images with the burst data of computer communications. Moreover, ATM is characterized by the fact that it can simultaneously perform communications over multiple service grades in which conditions such as speed, quality, security and so on are different, even if the data is in the same medium. In addition, because ATM performs only physical layer processing, many different kinds of protocols and services can be used for the top layer. Other advantages of ATM are that the type of connection can be freely selected as either branching or asymmetrical, the communications media can be freely added to or changed, and the destination can be freely selected or switched thanks to ATM's multiplexing functions and establish/release connection functions.

Then from the standpoint of the network, first of all, the structure of the net can be simplified, which makes it easier to operate and manage, thanks to ATM's uniform switching architecture. Moreover, the service control and the net operation management functions can be more sophisticated thanks to ATM's uniformity of and large capacity for service control and net operation management data. Furthermore, network resources can be effectively utilized by constructing the network in three tiers—a transfer medium net to provide the means for actual data transmission, and through multiplexing to different destinations on the same line, a VP net to provide appropriate transfer medium resources, and a VC net to actualize the various services. By altering the VP/VC capacity or the routing as needed in response to changes in traffic or to trouble situations, the network can be made quite flexible and highly reliable.

4. ATM-LAN

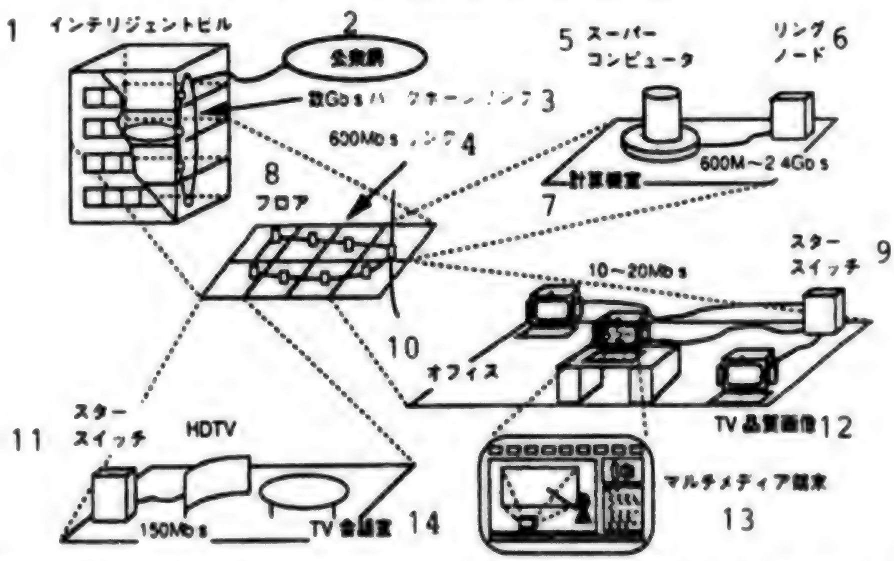
Below I will discuss the multimedia ATM-LAN, which is a next-generation, local access network system that takes advantage of these ATM features.

4.1 ATM-LAN and the Office of the Future

The areas of ATM-LAN application include services that existing LANs cannot handle such as audio and image media, which have small time-lag tolerances, and high-speed services that existing PBXs cannot handle such as image and high-speed data transfer. Therefore, we can expect the ATM-LAN to be widely used in the future for business infrastructures.

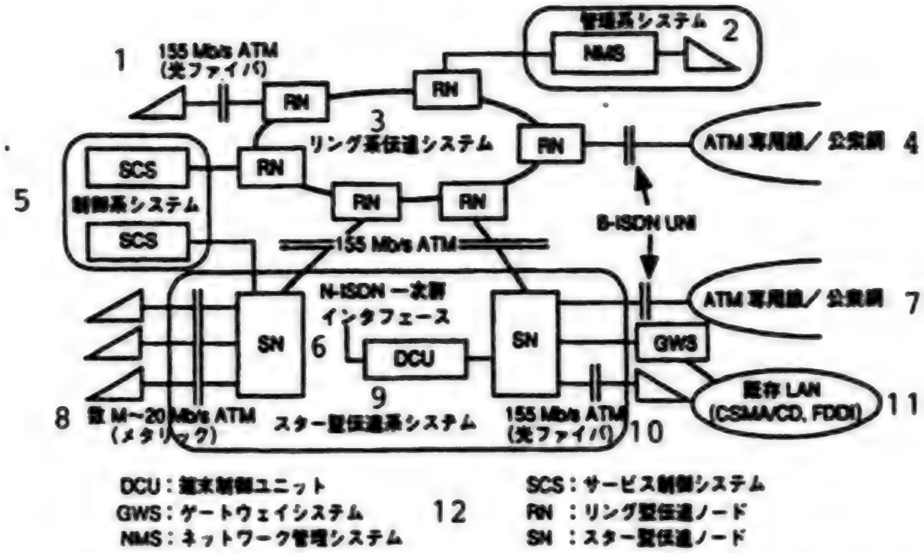
Figure 1 shows an example of an ATM-LAN being used as a business infrastructure. Each floor of the building is connected vertically by a several-Gb/s trunk network, and each floor has its own 600 Mb/s ATM ring LAN. Furthermore, ATM star switches provide a 150 Mb/s high-speed interface and a metric cable-linked 10-20 Mb/s medium-speed interface to each office on the floor. A TV conferencing system and a multimedia terminal are connected to each interface, which enables the use of a variety of multimedia services.

Fig. 1 ATM-LAN and the Office of the Future



Key: 1. Intelligent building; 2. Public network; 3. Several-Gb/s backbone ring; 4. 600 Mb/s ring; 5. Supercomputer; 6. Ring node; 7. Computer room; 8. Floor; 9. Star switch; 10. Office; 11. Star switch; 12. TV-quality image; 13. Multimedia terminal; 14. TV conference room.

Fig. 2 Example of ATM-LAN Structure



Key: 1. 155 Mb/s ATM (optical fiber); 2. Management system; 3. Ring transmission system; 4. ATM dedicated line/public net; 5. Control system; 6. N-ISDN primary group interface; 7. ATM dedicated line/public net; 8. Several M-20 Mb/s ATM (metric cable); 9. Star transmission system; 10. 155 Mb/s ATM (optical fiber); 11. Existing LAN (CSMA.CD, FDDI); 12. Abbreviations—DCU: Terminal control unit; GWS: Gateway system; NMS: Network management system; SCS: Service control system; RN: Ring transmission node; SN: Star transmission node

4.2 Structure of ATM-LAN

Figure 2 shows an example of the physical structure of the multimedia ATM-LAN system developed at NTT. This system increases the physical and theoretical independence of the various component systems—the transmission system (ring/star network), the control system, and the management system. A corporate communications infrastructure can be configured by flexible combinations of the various component systems. Moreover, the various theoretical component systems are configured into a virtual net, and by changing their linking relationships as needed, increased flexibility in terms of function distribution, control mechanisms, and performance can be achieved.

Moreover, the system is directed toward openness because the interfaces linking the various systems are all standardized. It has an independent mechanism for hooking up with other communications systems that acts as a gateway, and this enables interconnections with a variety of communications systems of different types.

The transmission system consists of a ring system, which provides an ultra high-speed interface up to 622 Mb/s, and a star system, which provides both a medium-speed interface of 10 Mb/s via a twisted pair cable and a high-speed interface of 155 Mb/s. It makes efficient use of transmission routes by employing the star transmission system mainly for consecutive, constant-speed data transmissions and the ring transmission system mainly for burst data transmissions. Moreover, it can respond flexibly to changes in the scale of use by combining the various ring and star transmission systems in hierarchies.

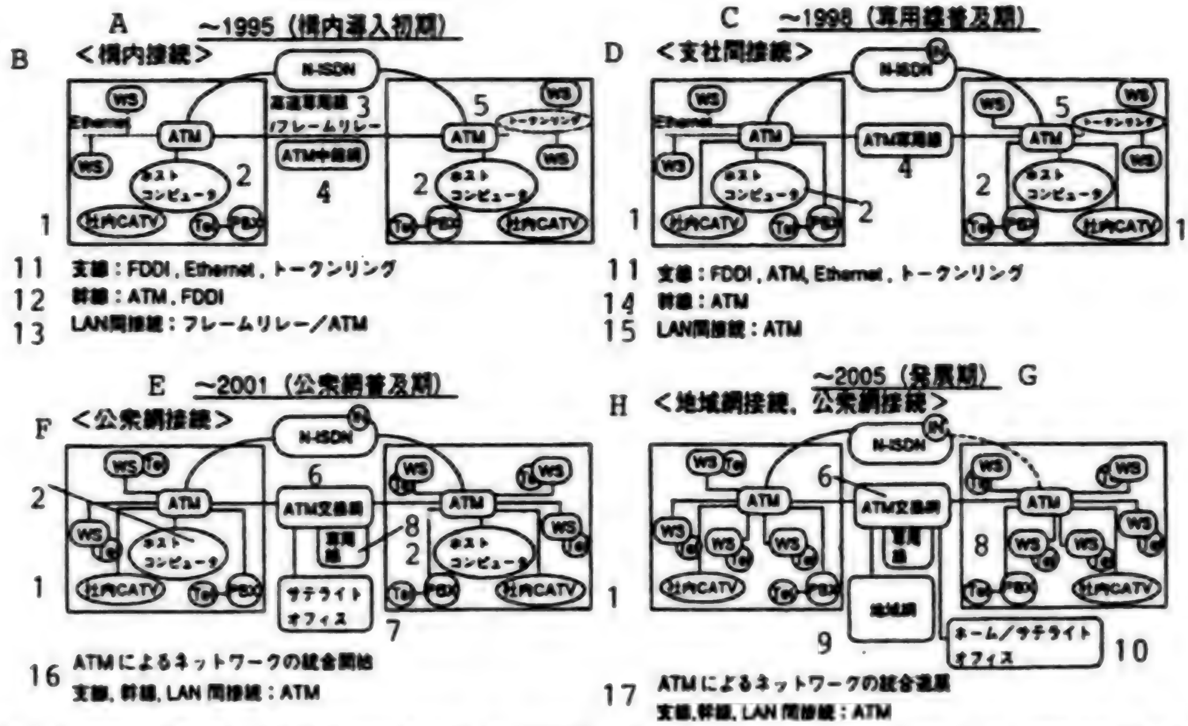
4.3 ATM-LAN Functions

Next I will introduce several examples of service functions provided by the ATM-LAN.

The ATM-LAN control system employs a structure consisting of three levels—switch control, connection control, and call control. It separates the concepts of call and connection, which enables a variety of multi-group and multi-connection call controls. Moreover the system links the functions of the various levels via ATM connections, which allows flexible response to changes in function distribution and network structure. More specifically, the ATM-LAN enables communications over a variety of connection forms such as unidirectional or bidirectional; synchronous or asynchronous; 1:1, 1:N or 1:many; fixed connection or switched connection; immediate connection or scheduled connection and so on.

With various combinations of these connection controls, it is possible to provide many services other than 1:1 communications such as 1:N, N:M multicasting services, and multimedia storage and multiple address services. For example, by utilizing the 1:N distribution service it is possible to provide multiple address services for the transmission of image data such as TV broadcasting and CATV.

Fig. 3 Development of Broadband Network Built Around ATM-LANs



Key: A. -1995 (Initial period of installation in companies); B. Intra-company connection; C. -1998 (Spread of dedicated lines); D. Connections to subsidiaries; E. -2001 (Spread of public network); F. Connection to public network; G. -2005 (Development period); H. Connection to regional and public networks; 1. Intra-company CATV; 2. Host computer; 3. High-speed dedicated lines/frame relay; 4. ATM relay network; 5. Token ring; 6. ATM switched net; 7. Satellite office; 8. Dedicated lines; 9. Regional net; 10. Home/satellite office; 11. Branch lines: FDDI, Ethernet, token ring; 12. Trunk line: ATM, FDDI; 13. LAN interconnection: Frame relay/ATM; 14. Trunk line: ATM; 15. LAN interconnection: ATM; 16. Beginning of integration of network by ATM; branch lines, trunk line, LAN interconnections: LAN; 17. Development of integration of network by ATM; branch lines, trunk line, LAN interconnection: ATM.

Moreover, with the ATM-LAN it is possible to realize an environment in which a variety of services coexist by making the functions that connect with existing systems independent, standardizing interfaces between systems, using an integrated management system, and using a hierarchical address structure to absorb the existing numerical system.

5. Development of a Broadband Network and its Services

It is predicted that the ATM-LAN described in the previous section will be installed as business networks before public networks become available, and that it will precede the demand for broadband services.

Below I will discuss the growth of a broadband network built around ATM-LANs[6] and the multimedia LAN services that will be available through it.

5.1 Development of a Broadband Network

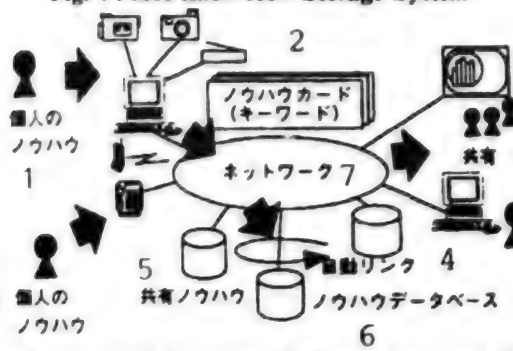
Figure 3 depicts the predicted development of a broadband network built around ATM-LANs and divides it into four time periods.

The first period depicts the introduction of ATM for intra-company networks. A variety of existing LANs such as FDDI and Ethernet will be used for the branched LANs, and ATM will mainly be used as a successor to TDM such as ATM-MUX, frame relay on ATM, and so on.

In the second period the ATM-LAN will be used for high-speed computer communications as IP-over-ATM. Moreover, ATM dedicated lines will be used for LAN interconnections.

Then in the third period, the ATM public network will be set up and its range of use will expand. Network integration of all intra-company branch/trunk lines and LAN interconnections will begin via ATM.

Fig. 4 FISH Know-How Storage System



Key: 1. Individual know-how; 2. Know-how cards (keywords); 3. Sharing; 4. Automatic link; 5. Shared know-how; 6. Know-how database; 7. Network.

Finally, in the fourth period we can expect integration of the network via ATM and it will be made intelligent.

5.2 Multimedia LAN Services

Above I mentioned that broadband corporate networks will precede public networks.

It is expected that multimedia LAN services that utilize broadband networks will also develop in response to this. More specifically, it appears that computer communication and multimedia services, including image-related services, will play an important role in the startup of broadband services, which will be based mainly on corporate use.

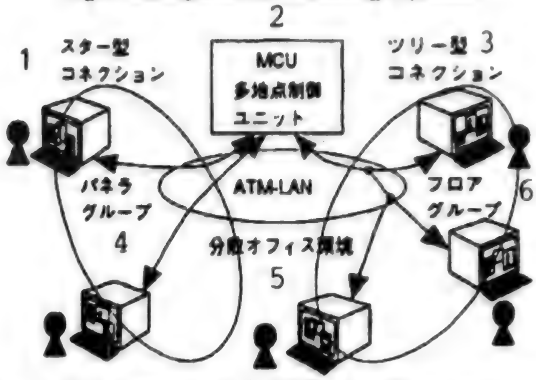
The computer communication services may include providing a seamless communications environment in which the user can freely set the speed, band, form of connection, time of connection and so on without being consciously aware of the interconnection between public and corporate networks, or providing a decentralized computing environment to tie together many computers connected on the network for performing high-load processing such as CAD/CAM while handling large amounts of data.

Prospective multimedia services include providing a location-free TV conferencing system that can utilize multimedia for TV conferences regardless of whether the participants are in the office or at an outside location, an image service that links offices at different locations with life-sized images and telepresence audio to provide landscape images and ambient music, and storage services such as video-on-demand service that will allow users to freely obtain necessary image data regardless of their location. They may also include other services such as virtual reality applications.

6. Examples of Multimedia LAN Service R&D

Here, I will introduce examples of current R&D on multimedia LAN service.

Fig. 5 Multipoint Conferencing System



Key: 1. Star connection; 2. MCU (multipoint control unit); 3. Tree connection; 4. Panelists; 5. Decentralized office environment; 6. Audience groups

6.1 Know-How Storage System

First I will discuss an example of computer communications service.

At our lab we have developed the FISH (Flexible Information Sharing and Handling) know-how storage system in which the know-how acquired by individuals is stored on the network and shared by the group. Right now we are conducting utilization tests in the lab.[7,8] This is an attempt to reconfigure knowledge possessed by individuals within an organization so that it can be used effectively by the organization as a whole.

As shown in Figure 4, FISH enables the sharing of multimedia data such as moving pictures, still pictures, audio, text and so on independent of location via multiple networks.

The separate entries of know-how data handled by FISH are stored on the network as cards consisting of keywords and contents. Links are formed between stored cards via the keywords, and related cards can be provided when the user accesses the data. The ATM-LAN has a strong affinity for setting up active links between these kinds of data.

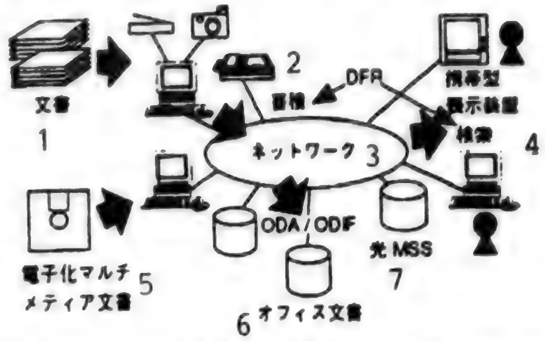
6.2 Multipoint Conferencing System

Next I will discuss a multipoint conferencing system, which is one example of an image service.[9,10]

As shown in Figure 5, in this system the ATM-LAN is used to link multiple, general-use personal computers to carry out a multimedia communications conference. By linking the ATM-LAN to a device called an MCU (Multipoint Control Unit), it will be possible for each terminal to receive and send communications and multimedia data to multiple members with the same feel as with 1:1 communications while needing almost no multipoint communications functions.

This system uses ATM high-speed circuits, and achieves high-quality image and audio communications. This differs from conventional conferencing systems, however,

Fig. 6 Mass Document Storage and Search System



Key: 1. Documents; 2. Storage; 3. Network; 4. Searching on portable display devices; 5. Electronic multimedia documents; 6. Office documents; 7. Optical MSS.

because it uses ATM-LAN unidirectional and bidirectional asymmetrical communications functions and multiple circuit simultaneous setting functions rather than continuously using the circuits with bidirectional symmetry, and this enables distribution of the same information to multiple members at multiple addresses. More specifically, just as in a panel discussion in which the panelists speak with members of the audience, this will enable communications between multiple groups at remote locations. Moreover, it realizes other features such as the display of a reduced composite image showing the status of participation of multiple members, automatic detection and display of the speaker, display of the status of various other conferences, remote camera control and so on.

6.3 Mass Document Storage and Search System

Next I will discuss a document storage and search system that uses the optical mass memory system (optical MSS or optical mass storage system)[11] as a prototype for a multimedia storage system.

The system shown in Figure 6 uses an optical MSS, which is a large-scale optical memory device with a capacity of 500 gigabytes. It is a system that uses the ODA/ODIF[12] document exchange format and the DFR[13] document search protocol, which are both international standards.

The optical MSS is a jukebox-shaped memory device that can hold as many as eight hundred 600 Mb optical magnetic disks. ODA/ODIF is a format for recognizing multimedia documents that contain not only text data but also geometric shapes and image graphics within the documents. DFR links the electronic filing systems of many different software vendors and is a communications protocol for realizing network-wide document storage and search.

This system enables mutual exchange of multimedia documents that already exist in electronic form via the network. Moreover, documents on paper can be stored on the optical MSS by using an image reader, and this enables conservation of paper resources and office space.

7. Future Issues for Multimedia LAN Service

I have introduced multimedia LAN services that will utilize a broadband network and given examples of R&D that is underway.

It will be necessary to overcome several problems, however, for these services to become widespread and reach individual users in the future.

First, it is important that the connections between intra-company networks and public networks be seamless. We must provide an integrated environment in which the user is not consciously aware of the structure of the network. We must do research on high-speed protocols and media processing, and on the allotment of functions to private and public nets in order to carry out computer communications effectively in a broadband environment. Prices of components such as ATM-LANs and multimedia terminals must come down for broadband services to become widespread.

Also, in terms of functions we have the problem of hooking up with existing networks. Because a network is a system with a large amount of inertia, we must envision the path of future development of existing networks and plan for the development of new networks. Furthermore, as the use of multimedia expands, we must not only deal with technical problems such as the development of image authoring tools, but we must also form a consensus in society concerning a variety of problems such as the immersion into an image-based culture and an organized approach toward copyrights.

8. Conclusion

I have discussed the current status and future prospects of multimedia LAN services that utilize a broadband network which is built around ATM-LANs.

Sophisticated communication services will bring us unimaginable convenience, but at the same time it can create a legion of unforeseen problems in the future, depending on how we use it.

The increased complexity due to sharing paradigms from multiple networks will bring about confusion and a sense of alienation in the user. We may be inundated by information, which will interfere with normal social activities. We must not forget as well that the abuse of telecommunications may cause many security problems such as invasion of privacy.

With respect to these problems, at NTT we will conduct future multimedia LAN service R&D under a new service paradigm called the S^3-View. This is based on providing only needed information in a timely manner (Selective), providing a safe, seamless work environment in which

security is adequately protected (Secure), and not burdening the user with complex networks and applications (Simple).

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Plan For Optical Access Network

94FE0551A Tokyo TOKYO NTT R&D in Japanese 10 Feb 94 pp 12-32

[Text]

Abstract

Increasingly high level demands in terms of both quantity and quality are being placed on telecommunications networks in line with the progress of the information society. More specifically, these demands are showing a tendency to move in the direction of visual, intelligent and personal services, or VI&P services.

In order to meet these demands, the Nihon Telegraph and Telephone Corporation (NTT) is currently digitizing its trunk lines and equipping them with advanced functions, and is about to embark on the all-out upgrading of its access network, which still supports an enormous amount of metal cable. The upgrading of this access network will require the installation of fiberoptic cable, which will enable that network to cope effectively with future changes in service requirements. Studies will have to be carried out to determine just what types of systems should be used for this ugrading work, what areas should be upgraded first, and how and at what pace this upgrading work should be carried out. This paper describes the current state of NTT's access network, and introduces some specific notions concerning the various tasks that lay ahead in making the switch to fiberoptic cable.

1. Introduction

In the past, the two major types of services provided via telecommunications networks were telephone and leased line services, which were narrow-band analog-based services for the most part. However, progress in the field of semiconductor technology has brought with it the appearance of digital telecommunication terminals, the numbers of which have grown by leaps and bounds in recent years. And the recent availability at reasonable prices of ultrahighspeed semiconductor devices and large-capacity compact disc read-only memory (CD-ROM) have spurred the upgrading of telecommunications terminals by equipping them with advanced functions, which in turn has raised the level - quantity and quality - of demands placed on telecommunications networks. At NTT, we have been advocating VI&P (visual, intelligent and personal) services as the types of services that will be offered in the 21st century, and today we find ourselves racing in that very direction.

To date, NTT has focused primarily on digitizing and upgrading the functions possessed by its trunk lines in order to meet these changing demands, but now the time has come to embark on the all-out construction of a digital broadband access network as well. The upgrading of this access network will require the installation of fiberoptic cable, which will enable that network to cope effectively with future changes in service requirements. And it will also be very important for the company to carefully consider just what types of systems should be used for this ugrading work, what areas should be upgraded first, and how and at what pace this upgrading work should be carried out. To achieve this, NTT has begun to study management procedures for creating an efficient fiberoptic network infrastructure based on small-size fixed wiring sections established by subdividing existing subscriber access areas. The company has also begun testing specific opticalization plans by introducing optical access systems (CT-RT and LD-SLT systems) that economically provide telephone, low-speed leased line and other analog-based narrow-band services to subscribers via muliplexing techniques used in conjunction with fiberoptic cables. Future technological advances and market impacts are expected to alter details of fiberoptic cable-laying schemes, but NTT has also devised a long-term plan for wiring homes with fiberoptic cable by the year 2015, and has carried out studies concerning specific approaches and the pace at which this work will have to be done to achieve this goal. Based on these studies, this paper attempts to describe just how NTT intends to accomplish its goal of creating an optical access network.

2. Telecommunications

2.1 Services

Before discussing the current state of NTT's access network and how the company intends to upgrade this network in future, let's take a look at the kinds of services NTT currently offers. Figure 1 shows the types of services offered by NTT as of March 1993. As the data furnished in this figure indicate, the overwhelming bulk of NTT's service offerings at present consists of analog telephone services provided to 57 million subscribers. Whereas demand for telephone service at one time had exceeded 2 million new subscribers per year, the recent recession has put a crimp in this growth rate. Nevertheless, new demand still exceeds 1.3 million subscribers per year, which means NTT must continue to invest quite heavily in new plants and equipment to keep pace.

Compared to its analog services, NTT's digital services are a relative drop in the bucket. However, since its inception in 1988, demand for the company's integrated services digital network (ISDN) services has increased tremendously, with roughly 70,000 circuits being installed during fiscal 1992 alone. As a result, NTT has been pushing forward at a rapid pace with the construction and/or installation of digital switching equipment and digital transmission lines. And because its access network is still comprised of huge amounts of metallic cable incapable of handling digital services, the company must also devise systematic measures for digitizing this network in future as well.

2.2 Network Equipment

Over the past several years, NTT has actively undertaken to digitize and upgrade its network equipment, and has all but finished work on its trunk network. To begin with, the company has upgraded to fiberoptic cable the twisted-pair and coaxial cables, i.e. metal cables, that comprised the junction or trunk circuit links between exchanges. By the end of 1993, NTT had strung roughly 36,000km of fiberoptic cable to serve as trunk lines alone, and if we include the branches of the trunk network, the total length of fiberoptic cable laid stretches for 73,000km. Thus, with the exception of reliability enhancement work and the addition of fiberoptic cable to handle increases in traffic, the basic upgrading of NTT's trunk network is practically finished.

Also, as of the end of fiscal 1993, all trunk exchanges had been digitized, with old switches being replaced by D60 digital exchanges. With this done, the trunk network can now be said to be 100% digitized.

The focus of investments in digitization has now switched to local exchanges, with total investments exceeding 500 billion yen for the current fiscal year. In the past, wired-logic crossbar (XB) exchanges were the primary means of switching calls. However, these electro-mechanical systems have limitations when it comes to rated services, and with the rapid increase in digital services, it became necessary to switch to digital exchanges nationwide. During the current fiscal year, NTT has introduced into its local exchange system enough digital switching equipment to handle over eight million terminals. A portion of this equipment was installed anew to handle one million new subscribers, and the remaining equipment replaced old exchanges handling the remaining seven million terminals belonging to existing subscribers. The company plans to

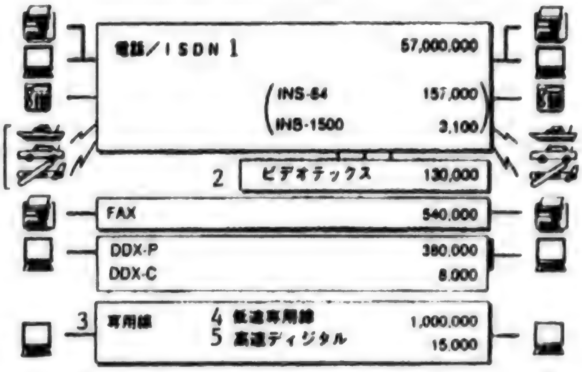

Figure 1. Services Currently Provided by NTT

Key: 1. Telephone/ISDN; 2. Videotex; 3. Leased Line; 4. Low-speed leased line services; 5. High-speed digital leased lines

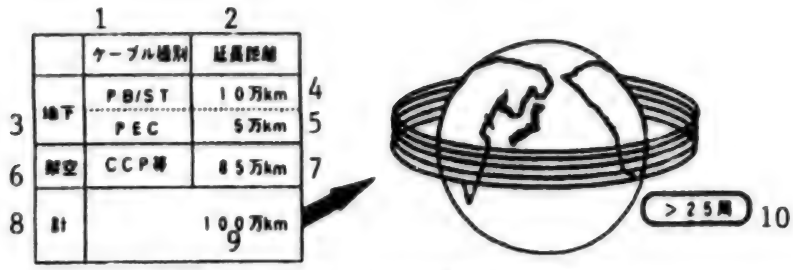

Figure 2. Current State of Subscriber Cables

Key: 1. Type of Cable; 2. Length of Cable (km); 3. Underground cable; 4. 100,000km; 5. 50,000km; 6. Aerial cable; 7. 850,000km; 8. Total; 9. 1,000,000km; 10. more than 25 times.

carry out at least as much digitization work next fiscal year as well, which means that by the end of fiscal 1994, it should have completed its short-range goal of achieving stored program control (SPC). Because SPC will facilitate the realization of various rated services, NTT will be able to provide a more complete service menu, which is expected to lead to increasingly fierce competition in the realm of services. However, there will still be a number of D10 analog-type exchanges in operation, which the company plans to have completely digitized by the end of fiscal 1997 at the latest. As digitization progresses, new types of services can be developed, which should result in the gradual shift away from rated service competition toward market competition.

As indicated by the data provided in Figure 2, the access network, which is the main theme of this paper, consists almost entirely of metal cable, and lots of it. Roughly 100,000km worth of the underground cable, or ⅔ of the total, comprises paper-insulated cable, while the remaining 50,000km worth of cable is wrapped in plastic insulation. With paper-insulated cable, it is very difficult to ensure the transmission quality of digitally-provided services, meaning that it will be necessary to systematically upgrade this cable to handle digital services. Practically all of the aerial cable, however, is of the plastic-insulated type, and aerial cable accounts for the overwhelming majority of the access network, measuring 850,000km in length. Together the total length of the underground and aerial cable comprising the access network works out to over one million kilometers, which if interconnected would stretch around the circumference of the earth over 25 times. And an additional 10,000km of metal cable is being laid every year to handle new subscribers. The move toward optical fibers will have to be rapidly promoted in order to construct an optical network.

2.3 Network Construction Trends

Figure 3 attempts to illustrate in a single diagram the progress of digitization. That is, trunk circuits and trunk exchanges have been almost 100% digitized, and local exchanges are scheduled to be completely digitized in the relatively near future (as of the end of fiscal 1997). When viewed from this perspective, you can readily see why the access network has become the target of future digitization efforts. The future digitization of this access network will require a number of years and considerable investments. This will make determinations regarding services an extremely important issue. More specifically, the prediction of market trends, such as, whether analog services will continue to be the main types of services provided in future or if digital services will become predominant, and whether or not broadband services should be expanded, will have a considerable impact on how the scenario for constructing a new infrastructure changes in future. Here at NTT, we have looked at service trends from a number of different angles, and realize how extremely difficult it is to make accurate predictions. However, industry trends viewed on a global scale seem to indicate the possibility of multimedia and other broadband services taking off in the not too distant future. Recent newspaper and magazine articles pointing to this trend are numerous, and because the service offerings envisioned are quite realistic as well as attractive, we feel we can count on this possibility to manifest itself.

3. Mission of the Access Network

3.1 Digital Network

NTT will have to increase the speed that its network operates at and make it capable of handling broadband transmissions so we can offer broadband services in future. But we do not expect demand for these services to be uniform nationwide, which means we will have to carry out market analyses on a region-by-region basis, and then based on those results, construct the necessary infrastructure in an economical manner.

At this point, I would like to touch on just what kind of a network NTT will have in future. Figure 4 illustrates the kind of network NTT has now, and what it conceivably will look like in future. The presentday network comprises analog and digital networks operating together, but in future, and the very near future at that, the entire network will be digital in nature. I will attempt to explain the concept behind this digital network by using the the Tokyo Dome stadium as an example. The "hardware" that comprises the Tokyo Dome (the artificial turf, bleachers and dome) can be equated to the actual digital network itself. Now there might be a few specialists, such as construction

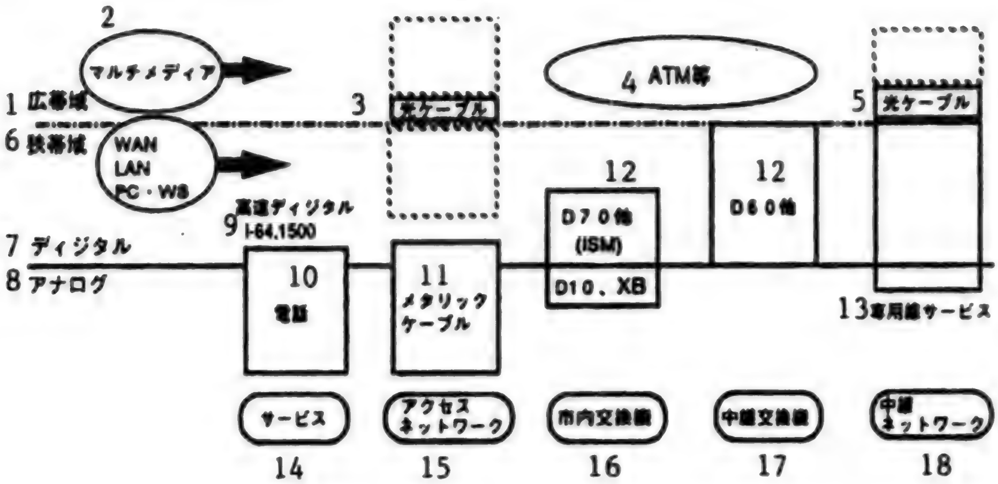

Figure 3. Network Construction Trends

Key: 1. Broadband; 2. Multimedia; 3. Fiberoptic cable; 4. ATM; 5. Fiberoptic cable; 6. Narrowband; 7. Digital; 8. Analog; 9. Highspeed digital; 10. Telephone; 11. Metal cable; 12. et al; 13. Leased line services; 14. Services; 15. Access network; 16. Local exchanges; 17. Trunk exchanges; 18. Trunk network.

engineers and the like who would come to the Tokyo Dome just to get a look at its hardware, but that hardware alone would not pack the bleachers to full capacity. The biggest factors in determining whether people will come to the Dome or not are the kinds of games and events held there, and just how well they are organized and carried out. In other words, it is the kinds of services and software offered via the digital network, and how well they are put together and presented, that will determine how satisfied subscribers will be with that digital network. And as for the access portion of the network, which links users' systems to the network, this can be equated to the roads, or the cars, trains and in some cases planes, that bring people to the Tokyo Dome for sporting and other events. That is, the access portion of the network is the means required for the user to access the network in order to take advantage of the services offered there. Therefore, if this access portion is not actively developed, numerous potential users will be unable to access the network. This access portion of the network comprises those transmission lines or circuits linking the NTT building with user buildings, as well as all the lines that run into subscriber households throughout the nation. And these circuits come in a variety of formats, including radio waves and hard-wired transmission lines, with the latter being either metal or glass (optical fiber). The access network has the vital mission of directly linking the users' systems up with the trunk network over which services are provided (See Figure 5). For this reason, the construction of this network, i.e. how it takes shape, is a major concern. The access portion of the network will also play a vital role in competition in future, and will therefore most likely offer considerable variety.

3.2 Development of the Access Network

Figure 6 introduces the access network's current configuration, and describes this configuration by broadly classifying it into the trunk network access configuration and the network configuration of the access network itself. At present, the trunk network access configuration is built for low-speed analog services, with the majority of user access being from fixed locations. That is, in the past, prior to the arrival of the age of portability, the points from which users could access the network, be it at the company or in the home, were limited to fixed locations. And because the network configuration at that time was based on metal cables, it took on the aspect of user multiplexing, which required that separate lines be hooked up for telephone and leased line services. Furthermore, as a result of metal cable transmission loss restrictions, subscriber access areas were relatively small, measuring less than seven kilometer in radius. There are over a 100 such access areas in the Tokyo area.

In the future, however, access methods will not be limited to conventional hard-wired transmission lines, but will incorporate a diverse number of access formats to include radio and satellite-based access systems. And the evolution of a Customer Control System (CCS) will enable the user to decide on his own which access format he wants to employ. The access network configuration will most likely move away from the user multiplexing of the past toward a service multiplexing approach. This will be made possible thanks to the large transmission capacity of fiberoptic cable. And because service multiplexing will enable network construction to be carried out more economically in future, NTT hopes to push rapidly forward with the laying of fiberoptic cables for the access network. Service multiplexing will make it possible to use a single glass fiber to make telephone calls, send facsimile messages, let your computer talk with someone else's and even receive image transmissions. Put another way, service multiplexing can be thought of as having a "data outlet" installed at the user

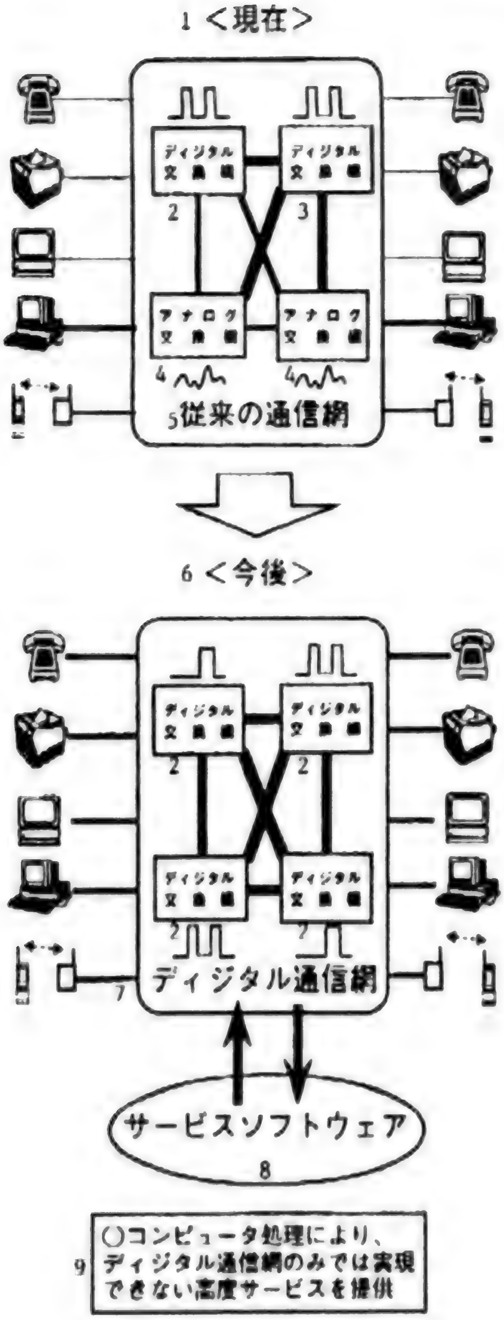

Figure 4. Concept of NTT's Future Network

Key: 1. Present; 2. Digital Exchange; 3. Digital Exchange; 4. Analog Exchange; 5. Conventional Netowrk; 6. Future; 7. Digital Network; 8. Service Software; 9. Use of computer processing to provision of advanced services incapable of being realized via the digital network alone.

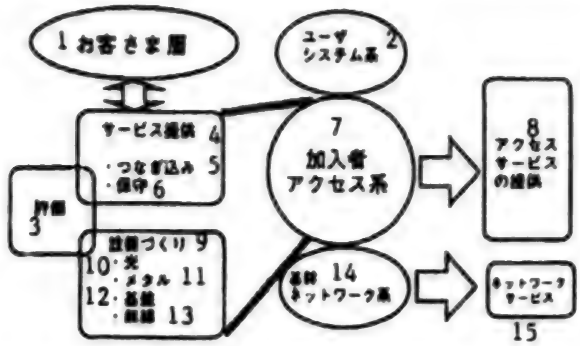

Figure 5. Mission of Subscriber Access Network

Key: 1. User Layer; 2. User systems; 3. Evaluation; 4. Service provision; 5. Hook up; 6. Maintenance; 7. Subscriber Access Network; 8. Provision of access services; 9. Equipment production; 10. Fiberoptic cable; 11. Metal cable; 12. Infrastructure; 13. Radio; 14. Trunk Network; 15. Network services.

end of the access portion of the network, into which can be plugged a variety of different types of telecommunications terminals for receiving a wide range of services. And because transmissions will be carried out over long distances, it will be possible to employ more flexible configurations for access areas as well. For example, we expect to see a lot of access area integration.

4. Details of NTT's Opticalization Plans

4.1 Management in Terms of Fixed Wiring Sections

Up to this point, I've focused on the status of NTT's overall network and the mission of the access portion of that network. Now I would like to furnish you with a more detailed description of just how NTT intends to construct a fiberoptic cable-based access network. First, I will give you some insights into NTT's thinking regarding where to begin its opticalization of the access network. In promoting the construction of a fiberoptic cable-based access network, it will be vital for us to determine just where demand for broadband services will be generated, and how to study market trends related to that demand. NTT is expending considerable effort to establish new management procedures for grasping this type of information using as a basis fixed wiring sections formed by further subdividing existing access areas. The company will use this new procedure to determine the potential demand of access areas by conducting detailed surveys in each of the fixed wiring sections that comprise an area, analyzing the various user groups/brackets and estimating demand for each type of service by section to become totally familiar with the characteristics of each area. Then, based on these findings, the company will decide if a particular area is ripe for all-out opticalization, or can continue to make do with metal cables for the time being. When it comes to analyzing an area in this way, if the sections into which that area is divided for analysis purposes are too large or

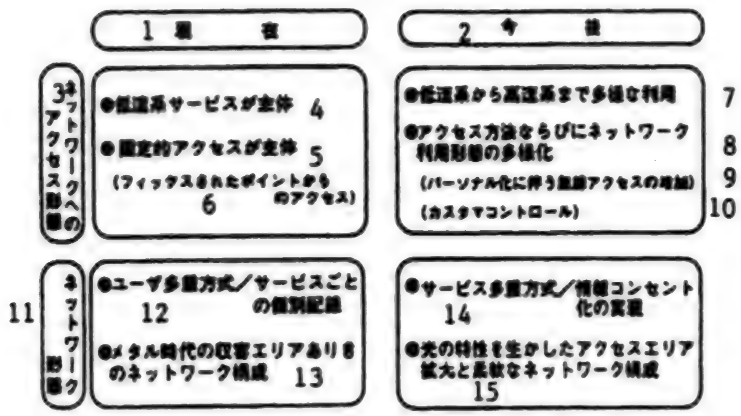

Figure 6. Evolution of the Access Network

Key: 1. Present; 2. Future; 3. Network Access Configuration; 4. Low-speed services; 5. Fixed access points; 6. (Access from fixed points only); 7. Various utilization speeds ranging from low- to high-speed; 8. Diversified access methods and network utilization formats; 9. (Increase of radio-based access in line with move toward personal services); 10. (Customer control); 11. Network Configuration; 12. User multiplexing/separate lines for each type of service; 13. Conventional network configurations for metal cable era access areas; 14. Service multiplexing/realization of data outlets; 15. Enlarged access areas that take advantage of properties of light and flexible network configurations.

too small, then this analysis process can prove ineffective and/or the workload can grow so large that the effort proves inefficient. The fixed wiring sections comprise roughly 600 subscribers each. This figure (600 subscribers) has been used as the basic unit for past demand forecasts, as well as for facilities construction, and therefore should serve to facilitate information gathering and to make construction work more economical. NTT therefore feels that at this point it should be able to make full use of this figure as the basic unit of its new management strategy as well. And when it comes to large user buildings, since a single user building can account for over 600 subscribers, and/or can be linked up directly to multiple underground cables, each user building is treated as an individual fixed wiring section.

4.2 Optical Access System

Next, I would like to discuss the types of systems NTT is looking at for upgrading to fiberoptic cable. As indicated in Figure 1, the majority of NTT's services at the present time fall into the category of narrow-band analog services. And how it decides to handle these services will be vitally important. That is, the facilities construction methods will greatly change depending on whether the company decides to continue providing its narrow-band analog services via metal cables as it has done to date, or to incorporate these services into its fiberoptic cable offerings. Those areas being targeted initially for all-out opticalization include major cities like Tokyo, Nagoya and Osaka, as well as other government designated cities considered to possess high-potential areas. But because these areas are already cram packed with facilities such as pipes and conduits, and because of the huge investments required to construct new civil engineering facilities there, the most economical approach to promoting fiberoptic cable-laying projects in these areas will be one that doesn't generate any civil engineering projects. More specifically, as indicated by Method 1 shown in Figure 7, the most likely approach to be used from an economical standpoint is one whereby existing cables are removed and fiberoptic cable laid in the same conduits that had held the metal cable, albeit with much more room to spare. NTT will then develop an optical access system capable of providing existing narrow-band analog telephone and leased line services, and then use this system as a basis for further promoting its opticalization plans. Optical access systems currently available include the CT-RT system, which is capable of providing multiplexed transmission telephone services, and the LD-SLT system, that can transmit low-speed analog leased line services using a similar multiplexing technique. The CT-RT system comes in two types: the type that can be installed in user buildings, and the type that can be installed outdoors. Both of these types are capable of handling between 100-2,000 circuits. This kind of circuit-handling capability makes the CT-RT system an economical system for installation in relatively large user buildings. And to promote the economical opticalization of small-and medium-sized user buildings, NTT plans to develop a small-scale 30-circuit version of the CT-RT system by the end of fiscal 1994. The company also has three types of LD-SLT systems available capable of handling between 24-672 circuits, and has developed a version of this system capable of being integrated with a CT-RT system. This LD-SLT integration system was introduced in December 1993.

4.3 Fiberoptic Cables for Subscribers

In its efforts to opticalize the access network, NTT intends to commence fiberoptic cable-laying work in metropolitan

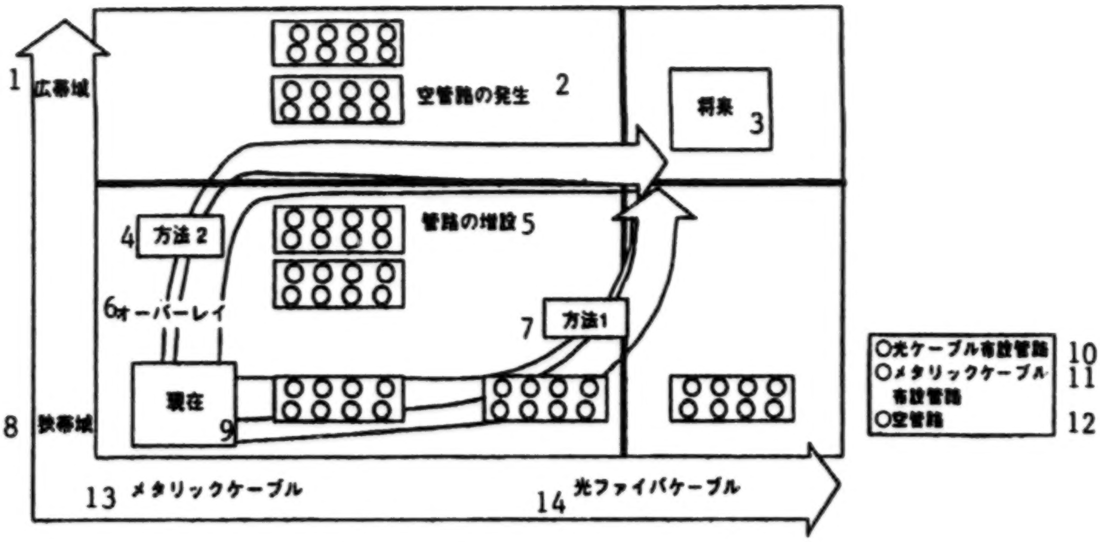

Figure 7. Methods for Opticalizing Access Systems

Key: 1. Broadband; 2. Generation of empty cable conduits; 3. Future; 4. Method 2; 5. Augmentation of cable conduits; 6. Overlay; 7. Method 1; 8. Narrow band; 9. Present; 10. Fiberoptic cable conduits; 11. Metal cable conduits; 12. Empty cable conduits; 13. Metal cable; 14. Fiberoptic cable.

business areas, where demand for high-speed, broadband services is expected to concentrate initially. Next, fiberoptic cables will be laid in the residential areas of these major cities, and run out to the business areas of mid-sized cities, following which the company will steadily expand its opticalization project into outlying areas as well. As indicated in Figure 8, multi-core fiberoptic cables will be laid out in loop or ring topologies in the metropolitan business areas to better provide the numerous vital services subscribers in these areas will require. This approach is also designed to enhance reliability and heighten NTT's ability to rapidly respond to sudden onrushes of demand. The opticalization of mid-sized cities in outlying areas will concentrate on stringing fiberoptic cables in the central areas of these cities, as well as into newly constructed public housing developments and industrial parks there, where new demand for telephone services exists. More specifically, the company is considering installing RT-BOXs and pole-mounted RTs to make the opticalization of these areas as economical as possible. And in the remote rural areas of Japan, where demand for high-speed, broadband services will be sparse, NTT plans to economize its opticalization operations by relying primarily on small-core fiberoptic cable.

4.4 Investment Plans

NTT's network will be completely digitized by fiscal 1997, and the company believes that highspeed digital and broadband services will come into increasing demand thereafter. In order to provide these kinds of services, NTT will have to upgrade network facilities, to include access systems. NTT has announced short-range plans that call for outfitting government-designated cities with optical access systems by the year 2000, medium-range plans aimed at expanding this opticalization project to other access areas after that, and a long-range goal of making possible the provision of VI&P services to every household in Japan by 2015. To realize this goal, the company calculates that it will have to invest a total of roughly 45 trillion yen over a period of approximately 20 years. No matter how you view it, this is a huge investment, and poses a tremendous risk for NTT management. But the company intends to muster all its resources in its efforts to reach its goal.

5. Afterword

Up to this point, I have focused on the thinking behind NTT's opticalization of its access network, but I will conclude by talking about the diverse undertakings and tasks related to the construction of this optical access network. First, there is the personal handy phone service experiment which got underway in Sapporo, Hokkaido in October 1993. The results obtained from these tests are expected to make a significant impact on the construction of the optical access network. Another undertaking that bears mentioning here is the "Next Generation Telecommunications Network Pilot Model" to be sponsored by the Ministry of Posts and Telecommunications. This project is scheduled to be carried out between 1994 and 1996 in the "Kyoto-Osaka-Nagoya Area" of the Kansai District, and is scheduled to begin tests involving 300 ordinary households located in that area. The services to be provided via this project will include the integrated services digital network (ISDN) and other services currently being offered in that area, to which will be appended cable television (CATV) and high vision television broadcast services. This

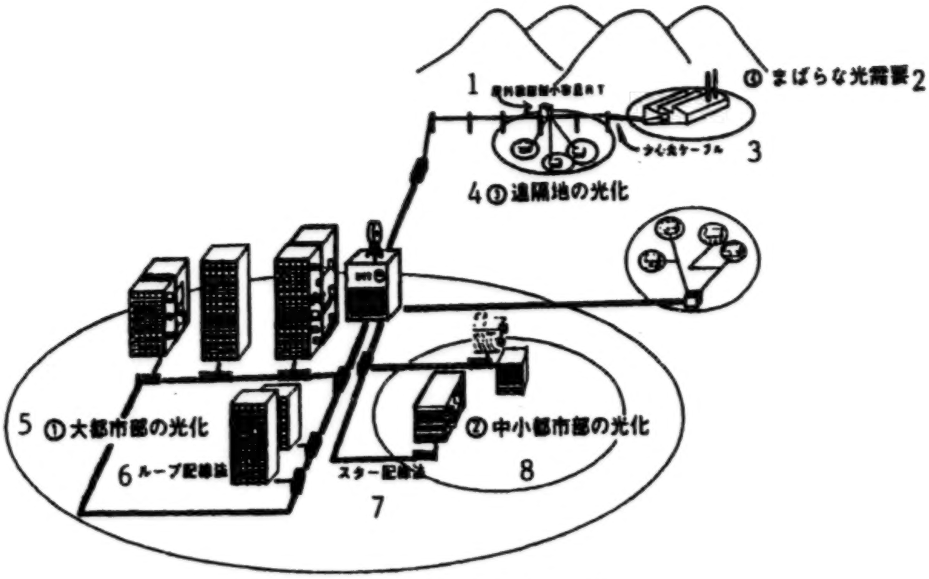

Figure 8. Fiberoptic Cable for Subscribers

Key: 1. Outdoor small-capacity RT; 2. (4) Sparse demand for optical services; 3. Small-core fiberoptic cable; 4. (3) Optiealization of remote areas; 5. (1) Opticalization of metropolitan areas; 6. Loop topologies; 7. Star topologies; 8. (2) Opticalization of small- and medium-sized cities

will mark the first time that a specific government-sponsored project has merged telecommunications and broadcasting together here in Japan. We are keenly interested in and hopeful of the outcomes of these various studies, and will continue to monitor their progress closely in future.

Next, let me introduce two tasks that will prove keys to the opticalization of NTT's access network in future. The first of these will be to lower the price of optical access systems. In the case of opticalization work utilizing CT-RT systems, there is, of course, the price of the system itself, to which must be added the high costs of refitting user buildings with reinforced floors, air conditioning systems and other facilities for the installation of that system. And there are instances when the costs of this refitting work are on a par with the price of the system itself, making this a big problem indeed. The next task will be pacing the development of user systems for the creation and provision of new services. In line with the future upgrading of the information infrastructure, it will be vital to develop, and drum up demand for, service software for use with that upgraded infrastructure. For its part, NTT, together with actively promoting its opticalization plan and striving to create markets for related services, will also undertake to develop its own services and the user systems needed to provide those services. This kind of all-out effort will undoubtedly prove a key factor in realizing an advance information society.

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